Medtronic

MARQUIS™ DR 7274

Dual Chamber Implantable Cardioverter Defibrillator

Reference Manual

Caution: Federal law (USA) restricts this device to sale by or on the order of a physician or properly licensed practitioner.

MARQUIS DR 7274

Reference Manual

A guide to the operation and programming
of the Model 7274 Marquis DR Dual Chamber
Implantable Cardioverter Defibrillator

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Introduction

Using this manual

Before implanting the ICD, it is strongly recommended that you:

- Refer to the product literature packaged with the ICD for information about prescribing the ICD.
- Thoroughly read this manual and the technical manuals for the leads used with the device.
- Discuss the procedure and the ICD system with the patient and any other interested parties, and provide them with any patient information packaged with the ICD.

Contacting technical support

Medtronic employs highly trained representatives and engineers located throughout the world to serve you and, upon request, to provide training to qualified hospital personnel in the use of Medtronic products.

In addition, Medtronic maintains a professional staff of consultants to provide technical consultation to product users. For medical consultation, Medtronic can often refer product users to outside medical consultants with appropriate expertise.

For more information, contact your local Medtronic representative, or call or write Medtronic at the appropriate address or telephone number listed on the back cover.

Customer education

Medtronic invites physicians to attend an education seminar on the complete ICD system. The course includes indications for use, an overview of ICD system functions, implant procedures, and patient management.

References

The primary reference for background information is Zacouto FI, Guize LJ. Fundamentals of Orthorhythmic Pacing. In: Luderitz B, ed. *Cardiac Pacing Diagnostic and Therapeutic Tools.* New York: Springer-Verlag; 1976: 212-218.

See these additional references for more background information:

- Singer I, Ed. *Implantable Cardioverter-Defibrillator*. Armonk, NY: Futura Publishing Co. 1994.
- Singer I, Barold SS, Camm AJ, Eds. *Nonpharmacological Therapy of Arrhythmias for the 21st Century: The State of the Art*. Armonk, NY: Futura Publishing Co. 1998.
- Estes M, Manolis AS, Wang P, Eds. *Implantable Cardioverter-Defibrillators*. New York, NY: Marcel Dekker, Inc. 1994.
- Kroll MW, Lehmann MH, Eds. *Implantable Cardioverter-Defibrillator Therapy: The Engineering-Clinical Interface*. Norwell, MA: Kluwer Academic Publishers 1996.

Notice

This software is provided as an informational tool for the end user. The user is responsible for accurate input of patient information into the software. Medtronic makes no representation as to the accuracy or completeness of the data input into the software. MEDTRONIC SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTIAL OR CONSEQUENTIAL DAMAGES TO ANY THIRD PARTY WHICH RESULTS FROM THE USE OF THE INFORMATION PROVIDED IN THE SOFTWARE.

Abbreviations and acronyms

A- Atrial

AF Atrial Fibrillation

AFib/AFlutter Atrial Fibrillation and/or Atrial Flutter

ARP Atrial Refractory Period

ATP Antitachycardia Pacing

AVP Atrial Vulnerable Period

BOL Beginning of Life

bpm beats per minute

CNID Combined (VT and VF) Number of Intervals to Detect

CV Cardioversion

DF/Defib Defibrillation

ECG Electrocardiogram

EGM Electrogram

EOL End of Life

ERI Elective Replacement Indicator

FDI Fibrillation Detection Interval

FTI Fast Ventricular Tachycardia Detection Interval

FVT Fast Ventricular Tachycardia

ICD Implantable Cardioverter Defibrillator

J joules

min^{-1} reciprocal minutes; for example, pacing pulses per minute

ms milliseconds

mV millivolts

NCAP Non-Competitive Atrial Pacing

NID Number of Intervals to Detect

NST Non-sustained Tachycardia

PAC Premature Atrial Contraction

PAV Paced A-V Delay

PES Programmed Electrical Stimulation

PMT Pacemaker-Mediated Tachycardia

P-P an atrial interval

ppm paces or pulses per minute

P-R an interval between a P-wave and the subsequent R-wave

PVAB Post Ventricular Atrial Blanking period

PVARP Post Ventricular Atrial Refractory Period

PVC Premature Ventricular Contraction

RAAV Rate Adaptive A-V delay

RNID Number of Intervals to Redetect

R-P an interval between an R-wave and the subsequent P-wave

R-R a ventricular interval

SAV Sensed A-V Delay

ST/Sinus Tach Sinus Tachycardia

SVT Supraventricular Tachycardia

TDI Tachycardia Detection Interval

V volts

V- Ventricular

VF Ventricular Fibrillation

VF NID VF Number of Intervals to Detect

VRS Ventricular Rate Stabilization

VSP Ventricular Safety Pacing

VT Ventricular Tachycardia

VT NID VT Number of Intervals to Detect

Part I

Quick overview

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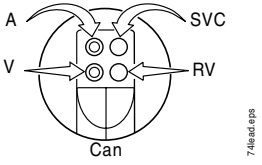
Physical characteristics

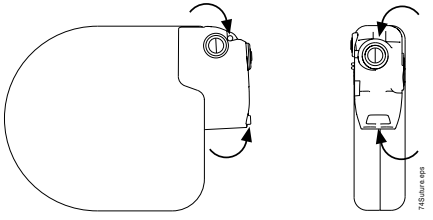
Table 1-1. ICD physical characteristics[a]

Volume	36 cc
Mass	75 g
H x W x D[b]	68.3 mm x 50.8 mm x 13.9 mm
Surface area of device can	66 cm^2
Radiopaque ID[c]	PKC
Materials in contact with human tissue[d]	Titanium / polyurethane / silicone rubber
Battery	Lithium silver vanadium oxide
Connectors	Two IS-1 connectors for pacing and sensing, Two DF-1 connectors for high voltage therapy, Active Can electrode (programmable)



Device Port	Connector Type	Software Name
SVC	DF-1	HVX
RV	DF-1	HVB
Can	n/a	HVA, Can
V	IS-1 bipolar	
A	IS-1 bipolar	

Suture holes



[a] Measurements are nominal values based on CAD (computer aided design) model measurements and are rounded to the nearest unit.

[b] Grommets may protrude slightly beyond the can surface.

[c] Engineering series number follows the radiopaque code.

[d] These materials have been successfully tested for the ability to avoid biological incompatibility. The device does not produce an injurious temperature in the surrounding tissue.

Magnet application

Bringing a magnet close to the device triggers changes in device operation as shown in Table 1-2. When the magnet is removed, the device returns to its programmed operations.

Table 1-2. Effects of magnet application on the device

Pacing mode	as programmed
Pacing rate and interval	as programmed[a]
VF, VT, and FVT detection	suspended[b]
Patient Alert audible tones (20 seconds or less)	with programmable alert(s) enabled: ▪ continuous tone (Test)[c] ▪ on/off intermittent tone (seek follow-up) ▪ high/low dual tone (urgent follow-up) with programmable alerts disabled: ▪ no tone ▪ high/low dual tone (urgent follow-up)

[a] Rate response adjustments are suspended while a Patient Alert tone sounds.

[b] Detection resumes if telemetry is established and the application software is running, or it resumes after the application software has started.

[c] The Test tone does not sound if “VF Detection/Therapy Off” is the only alert enabled.

Longevity projections

Longevity estimates are based on accelerated battery discharge data and device modeling at 60 ppm (min^{-1}) pacing rate, with:

- 2.5 V pacing pulse amplitude, 0.4 ms pacing pulse width, and 30 J delivered therapy energy (see Table 1-3)
- 3 V pacing pulse amplitude, 0.4 ms pacing pulse width, and 30 J delivered therapy energy (see Table 1-4)

This model assumes default automatic capacitor formation setting. As a guideline, each full energy charge decreases device longevity by approximately 24 days.

Device longevity is affected by how certain features are programmed, such as EGM pre-storage. For more information, see “Optimizing device longevity” on page 207.

Considerations for using EGM pre-storage
When the EGM pre-storage feature is programmed off, the device starts to store EGM following the third tachyarrhythmia event and also provides up to 20 seconds of information before the onset of the tachyarrhythmia, including:

- AA and VV intervals
- Marker Channel
- interval plot Flashback

When the EGM pre-storage feature is programmed on, the device also collects up to 20 seconds of EGM information before the onset of the arrhythmia.

In a patient who uniformly repeats the same onset mechanisms, the greatest clinical benefit of pre-onset EGM storage is achieved after a few episodes are captured.To maximize the effectiveness of the EGM pre-storage feature and optimize device longevity, consider these programming options:

- Turn pre-storage on to capture possible changes in the onset mechanism following significant clinical adjustments, for example, device implant, medication changes, and surgical procedures.
- Turn pre-storage off once you have successfully captured the information of interest.

Table 1-3. Projected longevity in years with 2.5V pacing amplitude and 0.4 ms pulse width

Percent pacing	Maximum energy charging frequency[a]	EGM pre-storage [b]	500 ohm pacing impedance		900 ohm pacing impedance	
			DDD	VVI	DDD	VVI
0%	Semi-Annual	Off	8.6	8.6	8.6	8.6
		On	8.5	8.5	8.5	8.5
	Quarterly	Off	7.5	7.5	7.5	7.5
		On	7.3	7.3	7.3	7.3
15%	Semi-Annual	Off	8.3	8.5	8.5	8.6
		On	8.1	8.4	8.3	8.5
	Quarterly	Off	7.2	7.4	7.3	7.5
		On	7.0	7.3	7.1	7.3
50%	Semi-Annual	Off	7.5	8.2	8.0	8.5
		On	7.4	8.0	7.9	8.2
	Quarterly	Off	6.6	7.1	7.0	7.3
		On	6.5	7.0	6.8	7.1
100%	Semi-Annual	Off	6.7	7.7	7.5	8.1
		On	6.5	7.5	7.3	8.0
	Quarterly	Off	6.0	6.8	6.6	7.1
		On	5.8	6.5	6.4	6.9

[a] Maximum energy charging frequency may include full energy therapy shocks or capacitor formations.

[b] The data provided for programming EGM pre-storage on is based on a 6 month period (two 3-month follow-up intervals) over the life of the device. Additional use of EGM pre-storage reduces longevity by approximately 25% or 3 months per year.

Table 1-4. Projected longevity in years with 3V pacing amplitude and 0.4 ms pulse width

Percent pacing	Maximum energy charging frequency[a]	EGM pre-storage [b]	500 ohm pacing impedance		900 ohm pacing impedance	
			DDD	VVI	DDD	VVI
0%	Semi-Annual	Off	8.6	8.6	8.6	8.6
		On	8.5	8.5	8.5	8.5
	Quarterly	Off	7.5	7.5	7.5	7.5
		On	7.3	7.3	7.3	7.3
15%	Semi-Annual	Off	8.1	8.5	8.4	8.6
		On	8.0	8.3	8.2	8.4
	Quarterly	Off	7.1	7.3	7.3	7.5
		On	6.9	7.2	7.1	7.3
50%	Semi-Annual	Off	7.2	8.0	7.8	8.3
		On	7.0	7.8	7.6	8.1
	Quarterly	Off	6.4	7.0	6.8	7.2
		On	6.2	6.8	6.7	7.0
100%	Semi-Annual	Off	6.2	7.3	7.1	8.0
		On	6.0	7.1	7.0	7.7
	Quarterly	Off	5.5	6.5	6.3	6.9
		On	5.4	6.3	6.1	6.8

[a] Maximum energy charging frequency may include full energy therapy shocks or capacitor formations.

[b] The data provided for programming ECG pre-storage on is based on a 6 month period (two 3-month follow-up intervals) over the life of the device. Additional use of EGM pre-storage reduces longevity by approximately 25% or 3 months per year.

Replacement indicators

Battery voltage and messages about replacement status appear on the programmer display and on printed reports. Table 1-5 lists the Elective Replacement Indicator (ERI) and the End of Life (EOL) conditions.

Table 1-5. Replacement indicators

Elective Replacement (ERI)	≤ **2.62 V**
End of Life (EOL)	**3 months after ERI**

ERI date – The programmer displays the date when the battery reached ERI on the Quick Look and Battery and Lead Measurements screens.

Temporary voltage decrease – The battery voltage temporarily decreases following a high voltage charge. If a battery measurement is taken immediately after a high voltage charge, the ERI or EOL indicator may be displayed. However, this is a temporary status which will return to normal when the battery has recovered from the charge.

EOL indication – If the programmer indicates that the device is at EOL, replace the device immediately.

Post-ERI conditions – EOL device status is defined as three months following an ERI indication assuming the following post-ERI conditions: 100% DDD pacing at 60 ppm (min^{-1}), 3 V, 0.4 ms; 500 Ω pacing load; and six 30 J charges. EOL may be indicated before the end of three months if the device exceeds these conditions.

Typical charge times

The most recent capacitor charge time appears on the programmer display and on printed reports and can be evaluated using the Charge/Dump test (see Table 1-6).

Table 1-6. Typical[a] full energy charge times

At Beginning of Life (BOL)	5.9 seconds
At Elective Replacement (ERI)	7.5 seconds

[a] These charge times are typical when the capacitors are fully formed.

High voltage therapy energy

The stored energy of the device is derived from the peak capacitor voltage and is always greater than the energy delivered by the device. Table 1-7 compares the programmed energy levels delivered by the device to the energy levels stored in the capacitors before delivery.

Table 1-7. Comparing delivered[a] (programmed) and stored[b] energy levels

Energy (J)			Energy (J)		
Delivered [a]/ Programmed	**Stored [b]**	**Charge Time[c] (sec)**	**Delivered [a]/ Programmed**	**Stored[b]**	**Charge Time[c] (sec)**
30	35	5.9	8	9.4	1.6
28	33	5.6	7	8.3	1.4
26	31	5.2	6	7.1	1.2
24	28	4.7	5	5.9	1.0
22	26	4.4	4	4.7	0.8
20	24	4.0	3	3.6	0.6
18	21	3.5	2	2.4	0.4
16	19	3.2	1.8	2.2	0.4
15	18	3.0	1.6	2.0	0.3
14	16	2.7	1.4	1.7	0.3
13	15	2.5	1.2	1.5	0.3
12	14	2.4	1.0	1.2	0.2
11	13	2.2	0.8	1.0	0.2
10	12	2.0	0.6	0.8	0.1
9	11	1.9	0.4	0.5	0.1

[a] Energy delivered at connector block into a 75 ohm load.

[b] Energy stored at end of charge on capacitor.

[c] Typical charge time at Beginning of Life (BOL) with fully formed capacitors, rounded to the nearest tenth of a second.

Stored data and diagnostics

Table 1-8. Stored data and diagnostics

Episode data	
Tachy episodes	150 VF/VT/FVT episodes: intervals, text, EGM
EGM capacity for tachy episodes	14 minutes of dual-channel EGM, or 23.5 minutes of single-channel EGM
SVT/NST episodes	50 SVT/NST episodes: intervals, text, EGM (the device does not usually store detailed episode records for NST episodes)

Table 1-8. Stored data and diagnostics (continued)

EGM capacity for SVT/NST episodes	2 minutes of dual-channel EGM, or 3.6 minutes of single-channel EGM
Brady episodes	53 mode switch episodes
EGM sources	9 options: atrial / ventricular / far-field
EGM options	Store before onset; Store during charging
Flashback memory	2000 intervals (containing both A-A and V-V): before latest VF, before latest VT, and before interrogation
Counter data	
Detection counters	Lifetime total, since cleared, and since last session
Episode counters	Episodes: ▪ VF, FVT, and VT ▪ Atrial Fibrillation / Atrial Flutter episodes ▪ Sinus Tach episodes ▪ Other 1:1 SVT episodes ▪ NST episodes ▪ Mode switch episodes Percentage pacing: ▪ AS-VS, AS-VP, AP-VS, AP-VP percentages Additional counters: ▪ Single PVCs and PVC runs ▪ Rate stabilization pulses and runs
Therapy efficacy counters	Counts for each VF, FVT, VT Therapy: ▪ Delivered ▪ Successful ▪ Unsuccessful ▪ Intervention (manually aborted) Total number of aborted shocks
Other stored data	
Patient Alert events	Up to 10 log entries: text and date for the first time an alert is triggered between interrogations
Battery and lead measurements	Battery voltage, last capacitor formation, last charge, lead impedance, EGM amplitude measurements, last high voltage therapy, and sensing integrity counter

Table 1-8. Stored data and diagnostics (continued)

Lead performance trends	14 days of daily measurements plus 80 weeks of weekly minimum and maximum measurements: ▪ Lead impedance: atrial pacing, ventricular pacing, defibrillation pathway, and SVC lead (if used) ▪ EGM amplitude: atrial (P-waves), ventricular (R-waves)
Cardiac Compass trends	14 months of measurement trends: ▪ VT and VF episodes per day ▪ High voltage therapies delivered per day ▪ Ventricular rate during VT or VF ▪ Episodes of non-sustained tachycardia per day ▪ Heart rate variability ▪ Total daily time in AF or AT ▪ Ventricular rate during AF or AT ▪ Percent pacing per day ▪ Patient activity ▪ Average day and night ventricular heart rate

New and enhanced features

The following features are new or changed from the 7275 GEM III DR ICD.

Patient management

RapidRead telemetry – Communication between the device and programmer is approximately 20 times faster than telemetry in previous Medtronic ICD devices. The magnitude of improvement depends on the amount and type of data that is interrogated. RapidRead telemetry is more reliable and has an increased range that makes placing the programming head easier.

Cardiac Compass trends report – This report displays up to 14 months of trend data related to tachyarrhythmia episodes, heart rate, and patient activity. See “Using Cardiac Compass to view long term clinical trends” on page 294.

Patient Alert – The alert duration when a magnet is applied to the device is now 20 seconds. The device also provides several new alerts:

- SVC (HVX) lead impedance out of range
- Active Can off without SVC
- DOO/VOO mode programmed
- VF Detection programmed off, or fewer than four VF therapies enabled for at least six hours
- charge circuit timeout occurred
- excessive charge time ERI

For more information, see “Using the Patient Alert feature” on page 253.

EGM amplitude trends – The device automatically measures R-wave and P-wave EGM amplitudes every day. These daily measurements are included in the data displayed on the Lead Performance Trends screen. See “Setting up data collection” on page 267.

EGM amplitude test – You can use the EGM Amplitude test to measure R-wave and P-wave EGM amplitudes. The results are reported on the EGM Amplitude Test screen. See “Measuring EGM Amplitude” on page 318.

Lead impedance measurement for SVC (HVX) – Along with other lead impedance measurements, the device provides an independent SVC (HVX) measurement to check the integrity of the supplementary high voltage electrode. See “Measuring lead impedance” on page 316.

Leadless ECG signal – If a supplementary high voltage electrode is placed in the SVC, the device provides the Leadless ECG signal through either the Can to SVC (HVX) or RV (HVB) to SVC (HVX) EGM source. See “Setting up data collection” on page 267.

Expanded pre-onset EGM storage – The device can now store up to 20 seconds of EGM before a tachycardia starts. See “Setting up data collection” on page 267.

Smart Auto Cap Formation – When the Auto Cap Formation Interval is set to Auto, the formation interval automatically adjusts to optimize device longevity and charge times. See “Smart Auto Cap” on page 206.

Ending a patient session – The device audits the programmed parameter settings when you end a patient session and alerts you if any of the settings are atypical. See “Starting and ending patient sessions” on page 230.

Tachyarrhythmia detection

VT Monitoring – VT detection can be set to Monitor, which allows the device to detect and record VT episodes without delivering therapy or influencing VF detection. See “Monitoring episodes for termination or redetection” on page 84.

High Rate Timeout – High Rate Timeout can turn off detection enhancements (Stability, PR Logic criteria) if a high rate episode is longer than a programmed duration. See “Details about High Rate Timeout” on page 102.

Tachyarrhythmia therapy

Episode confirmation during and after charging – The device continually monitors the ventricular rhythm during and after charging for cardioversion or defibrillation (when VF confirmation is active) to ensure the arrhythmia is present before delivering the high voltage shock. See “Confirming VF after initial detection” on page 115 and “Confirming VT or FVT after detection” on page 134.

Programmable Active Can – If a supplementary electrode is connected to the SVC (HVX) port, you can deselect the device Can as a high voltage electrode. See “Delivery pathway electrodes” on page 113.

Bradycardia pacing

Accelerometer-based rate response – The device uses an accelerometer to provide rate responsive pacing.

Additional bradycardia pacing modes – The device provides asynchronous pacing in the DOO and VOO pacing modes and provides the ODO mode to disable pacing. See Chapter 8, "Treating bradycardia" on page 147.

Enhanced AT-style Mode Switch – Mode Switch episodes are detected using a combination of the median atrial rate and the AF evidence criterion. See “Details about Mode Switch” on page 182.

EP studies

Defibrillation threshold testing support – The T-Shock and 50 Hz Burst induction screens allow you to monitor time between inductions, program ventricular sensing and VF therapy settings, adjust induction settings, select manual therapies, and retrieve episode records after therapy. See “How to perform defibrillation threshold testing” on page 45.

Backup VVI pacing during atrial inductions – You can choose to have the device deliver backup ventricular pacing during Manual Burst and PES inductions that are delivered to the atrium. See “EP Study overview” on page 324.

The Marquis DR system

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System overview

The 7274 Marquis DR Dual Chamber Implantable Cardioverter Defibrillator (ICD) system is an implantable medical device system that automatically detects and treats episodes of ventricular fibrillation, ventricular tachycardia, fast ventricular tachycardia, and bradyarrhythmia. The ICD system includes three major components:

- ICD

  The ICD senses the electrical activity of the patient's heart via the sensing electrodes of the implanted atrial and ventricular leads. It then analyzes the heart rhythm based on selectable sensing and detection parameters. If the ICD detects a tachyarrhythmia, it delivers defibrillation, cardioversion, or antitachycardia pacing therapy to the patient's heart. If the ICD identifies a bradyarrhythmia, it delivers bradycardia pacing therapy to the patient's heart.

- Leads

  The ICD can be used with transvenous or epicardial defibrillation leads. The lead system should consist of bipolar or paired unipolar[1] pacing/sensing leads in each chamber of the heart and one or two high voltage cardioversion/ defibrillation electrodes. You can program the Active Can device case as a high voltage electrode. The pacing and sensing electrodes in each chamber sense cardiac activity and deliver pacing stimuli.

- Programmer and software

  The Medtronic 9790C[2] programmer and 9966 application software allow you to

  - configure the detection, therapy, and bradycardia features for your patient
  - perform electrophysiological studies and system tests
  - monitor, display, or print patient cardiac activity information

[1] With an appropriate unipolar to bipolar adapter kit.
[2] With the model 9767 or 9767L programming head

For information about:

- indications, contraindications, lead compatibility, warnings and precautions, and patient selection, see the *Marquis DR 7274 Implant Manual*, which accompanies each device.
- basic programmer and software desktop functions that are not included in Chapter 10, "Using the programmer" on page 211, see the manual accompanying the programmer.
- installing the 9767 or 9767L programming head, see the manual accompanying the programming head.
- implanting leads, refer to the manuals accompanying the leads.

Detecting and treating tachyarrhythmias

The ICD monitors the cardiac rhythm for short ventricular intervals that may indicate the presence of VF, VT, or FVT.

- Upon detection of VF, the ICD delivers a biphasic defibrillation shock of up to 30 joules. If the VF episode persists, up to five more individually programmed defibrillation shocks can be delivered.
- Upon detection of VT, the ICD delivers either a Ramp, Ramp+, or Burst antitachycardia pacing therapy or a biphasic cardioversion shock of up to 30 joules synchronized to a ventricular depolarization. If the VT episode persists, up to five more individually programmed VT therapies can be delivered. You can also program the ICD to monitor the VT episode without delivering therapy.
- Upon detection of FVT, the ICD delivers either a Ramp, Ramp+, or Burst antitachycardia pacing therapy or a biphasic cardioversion shock of up to 30 joules synchronized to a ventricular depolarization. If the FVT episode persists, up to five more individually programmed FVT therapies can be delivered.

You can program the ICD to distinguish between true ventricular arrhythmias and rapidly conducted supraventricular tachycardia (SVT) and withhold therapy for SVT.

You can also program the ICD to detect a double tachycardia (an unrelated ventricular arrhythmia occurring simultaneously with an SVT), so that therapy is not withheld for a ventricular arrhythmia in the presence of an SVT.

Treating bradycardia

The ICD provides dual chamber rate responsive bradycardia pacing to optimize hemodynamics. An internal accelerometer senses the patient's physical activity, allowing the ICD to increase and decrease the pacing rate in response to changes in the level of activity.

Monitoring for real-time and stored data

The ICD and programmer provide real-time information on detection and therapy parameters and status during a patient session. The ICD also provides accumulated data on device operation, including stored electrograms, detected and treated tachyarrhythmia episodes, bradycardia interventions, and the efficacy of therapy. The Cardiac Compass report provides up to 14 months of clinically significant data, including arrhythmia episodes, therapies delivered, physical activity, heart rate, and bradycardia pacing activities.

All of this information can be printed and retained in the patient's file or saved in electronic format on a floppy diskette.

Conducting electrophysiologic tests

You can use the system to conduct non-invasive electrophysiologic studies including manual delivery of any of the ICD therapies to manage an induced or spontaneous tachyarrhythmia.

Alerting the patient to system events

You can use the programmable Patient Alert monitoring feature to notify the patient with audible tones if certain conditions related to the leads, battery, charge time, and therapies occur. The patient can then respond based on your prescribed instructions.

Indications and usage

The implantable cardioverter defibrillator is intended to provide ventricular antitachycardia pacing and ventricular defibrillation for automated treatment of life threatening ventricular arrhythmias.

Contraindications

The Marquis DR system is contraindicated for

- patients whose tachyarrhythmias may have transient or reversible causes, such as acute myocardial infarction, digitalis intoxication, drowning, electrocution, electrolyte imbalance, hypoxia, or sepsis.
- patients with incessant VT or VF
- patient who have a unipolar pacemaker
- patients whose primary disorder is bradyarrhythmias or atrial arrhythmias

Patient screening

Other optional screening procedures could include exercise stress testing to determine the patient's maximum sinus rate, and cardiac catheterization to determine if there is a need for concomitant surgery and/or medical therapy.

Emergency therapy

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How to deliver emergency cardioversion 28

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How to deliver emergency VVI pacing 30

Delivering emergency therapies

The device provides the following emergency therapies:

- defibrillation
- cardioversion
- fixed burst pacing
- emergency VVI pacing

The default emergency therapy is 30 joule defibrillation. When you select [Emergency] and [DELIVER], the device charges and delivers a biphasic 30 joule shock along the AX>B pathway[1].

The programmer resets the emergency defibrillation energy to 30 joules each time you select [Emergency]. Emergency cardioversion and fixed burst values remain as selected for the duration of the session.

To return to other programming functions from an Emergency screen, select [Exit Emergency].

Effect on system operation

The device suspends the automatic detection features when emergency defibrillation, cardioversion, or fixed burst pacing therapies are delivered. Detection is not suspended during emergency VVI pacing. Removing the programming head or pressing [Resume] turns detection on again.

Aborting an emergency therapy

As a safety precaution, the programmer also displays an [ABORT] button which immediately terminates any emergency therapy in progress.

[1] If Active Can is turned off, the defibrillation is delivered between the HVX and HVB electrodes.

On-screen and display panel buttons

The on-screen [Emergency] button and the red mechanical Emergency button by the programmer display panel function the same at all times.

Red Emergency Button Functions the same as on-screen [Emergency] button.

The on-screen [DELIVER] button and the yellow-on-blue mechanical Deliver button by the programmer display panel function the same during emergency operations only. The mechanical Deliver button operates only during emergency operations.

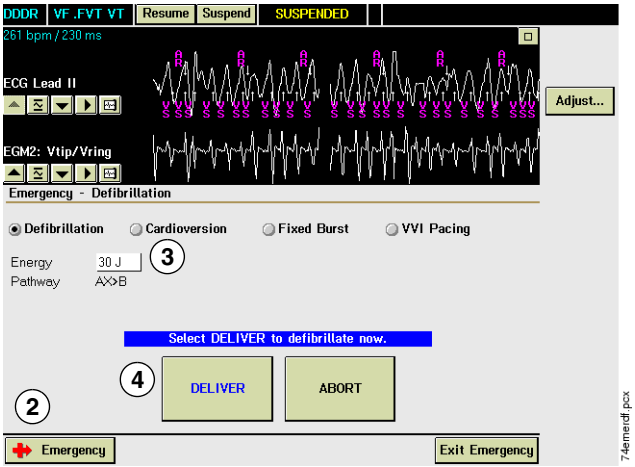
Yellow-on-blue Deliver Button Functions the same as on-screen [DELIVER], but only during Emergency functions.

Temporary parameter values

Emergency tachyarrhythmia therapies use temporary values that do not change the programmed parameters of the device.[1] These values are not in effect until you select [DELIVER]. After the tachyarrhythmia therapy is complete, the device reverts to its programmed values.

[1] Delivery of Emergency VVI Pacing changes the programmed bradycardia pacing values to the emergency values (see page 30).

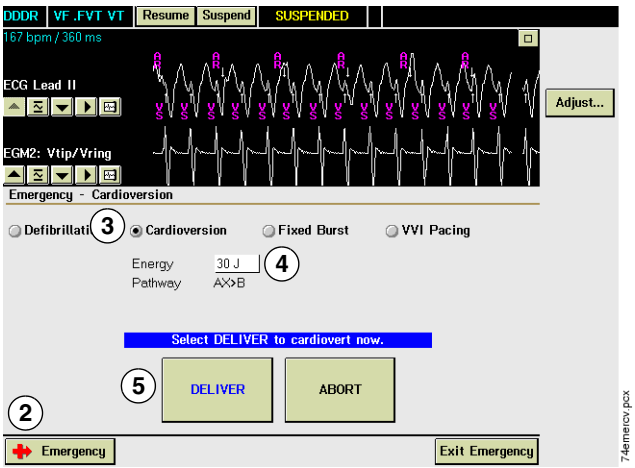
How to deliver emergency 30 joule defibrillation



1. Position the programming head over the device.
2. Select [Emergency].
3. Accept the defibrillation energy shown on the screen, or select Energy and select a new value from the window.
4. Select [DELIVER].

   If delivery is not confirmed, verify that the programming head is properly positioned and select [Retry] or [Cancel].

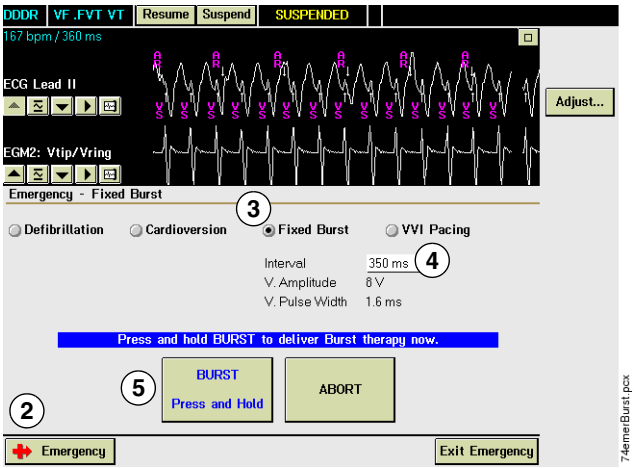
How to deliver emergency cardioversion



1. Position the programming head over the device.
2. Select [Emergency].
3. Select [Cardioversion].
4. Accept the cardioversion energy shown on the screen, or select Energy and select a new value from the window.
5. Select [DELIVER].

   If delivery is not confirmed, verify that the programming head is properly positioned and select [Retry] or [Cancel].

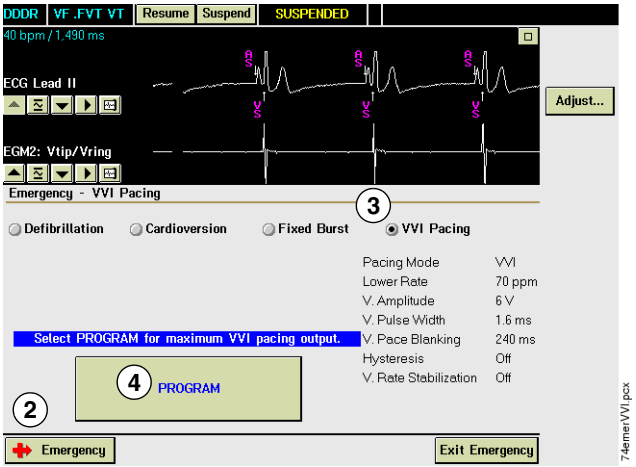
How to deliver emergency fixed burst pacing



1. Position the programming head over the device.
2. Select [Emergency].
3. Select [Fixed Burst].
4. Accept the pacing interval shown on the screen, or select Interval for a new interval value.
5. Select [BURST Press and Hold].

   If delivery is not confirmed, the programmer displays an error window. Verify that the programming head is properly positioned. Select [OK] from the window and reselect [BURST Press and Hold].

How to deliver emergency VVI pacing



1. Position the programming head over the device.
2. Select [Emergency].
3. Select [VVI Pacing].
4. Select [PROGRAM]. A successful programming sets the device to the following maximum output bradycardia pacing values.
   - Pacing Mode: VVI
   - Lower Rate: 70 ppm (70 min^{-1})
   - V. Amplitude: 6 V
   - V. Width: 1.6 ms
   - V. Pace Blanking: 240 ms
   - Hysteresis: Off
   - Ventricular Rate Stabilization: Off

If programming is not confirmed, verify that the programming head is properly positioned and select [Retry] or [Cancel].

Part II

Device implant and patient follow-up procedures

Implanting the ICD

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Connecting the leads to the ICD 40

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Overview

The tasks for implanting an ICD include

1. Preparing for an implant
2. Replacing an ICD
3. Positioning the leads
4. Testing sensing and pacing thresholds
5. Connecting the leads to the ICD
6. Testing defibrillation operation and effectiveness
7. Positioning and securing the ICD
8. Completing the implant procedure

These tasks are described in the sections that follow.

Preparing for an implant

⚠ **Warning:** Keep a back-up external defibrillator available during the implant for transthoracic rescue when arrhythmias are induced.

Equipment for an implant

- Model 9790c programmer and Model 9767 or 9767L programming head
- 9966 software application
- 8090 Analyzer lead analysis device or equivalent pacing system analyzer
- external defibrillator
- 5358 Defibrillator Implant Support Device and software application (optional)

Sterile supplies

- Marquis DR ICD and lead system components
- Programming head sleeve or programming head
- Analyzer cables
- Lead introducers appropriate for the lead system
- Extra stylets of appropriate length and shape

How to prepare for implanting

Set up the implant support instrument

When using an implant support instrument such as the 5358 Defibrillator Implant Support Device:

1. Calibrate any monitoring or recording equipment while recording the EGM and marker outputs of the support instrument.
2. Verify the high energy output of the support instrument by delivering a high energy defibrillation shock into the test load.

Set up the programmer and start the application

1. Set up the programmer as described in the instructions provided with the programmer.
2. Install the Marquis DR Model 9966 software on the programmer, if it is not already installed.
3. Place the programming head over the device and start the application. Select the device model or select [Auto identify].

   Note: The programmer automatically interrogates the device when the application starts.

Preprogram the device

Before opening the sterile package, prepare the ICD for implant as follows:

1. Check the “use by” date printed on the package. Do not implant the device after the “use by” date because the battery’s longevity could be reduced.
2. Interrogate the ICD, and print a full summary report.
3. Confirm that the battery voltage is at least 3.0 V at room temperature.[a]

   If the device has been exposed to lower temperatures or has delivered a recent high voltage charge, the battery voltage will be temporarily lower.
4. Set up data collection parameters and the ICD internal clock (see page 269).
5. Perform a manual capacitor formation (see page 320).
6. Program the therapy and pacing parameters to values appropriate for the patient (see page 151). Ensure that all tachyarrhythmia detection is programmed Off (see page 58).

[a] Use the Quick Look screen to verify the voltage, see page 251.

Replacing an ICD

If you are replacing a previously implanted ICD, turn off ICD detection and therapies before explanting.

When implanting the ICD with a chronic lead system, perform the following evaluations to ensure appropriate detection and therapy:

- Check the integrity of the chronic high voltage leads with a test shock, chest X-ray, and inspection.
- Perform chronic pacing and sensing measurements.
- Measure high voltage lead impedances.
- Test defibrillation efficacy.
- Confirm adequate sensing during VF.
- Ensure proper fit of the lead connectors in the ICD connector block.

Notes:

- To meet the implant requirements, it may be necessary to reposition or replace the chronic leads or to add a third high voltage electrode.
- Any unused leads that remain implanted must be capped.

How to explant and replace an ICD

1. Program all tachyarrhythmia detection Off.
2. Dissect the leads and the ICD free from the surrounding tissues in the surgical pocket. Be careful not to nick or breach the lead insulation during the process of exposing the system.
3. Loosen each setscrew, and gently retract the lead from the connector block.
4. Remove the ICD from the surgical pocket.
5. If the connector pin of any implanted lead shows signs of pitting or corrosion, replace the implanted lead with a new lead. The damaged lead should be discarded and replaced to assure the integrity of the device system.
6. Measure sensing, pacing, and defibrillation efficacy using the replacement ICD or an implant support instrument.
7. Evaluate the defibrillation efficacy of the replacement system.

Positioning the leads

Implant endocardial leads according to the supplied instructions, unless suitable chronic leads are already in place. Do not use any lead with this device without first verifying connector compatibility (refer to the *Marquis DR 7274 Implant Manual*). Transvenous or epicardial leads may be used. A bipolar atrial lead with closely spaced pacing and sensing electrodes is recommended.

Using transvenous leads

Use standard transvenous implant techniques to position the ventricular lead tip in the right ventricular apex and the atrial pacing lead tip high on the right atrial appendage.

Follow the general guidelines below for initial positioning of other transvenous leads (the final positions are determined by defibrillation efficacy tests):

- SVC (HVX) lead: Place the lead tip high in the innominate vein, approximately 5 cm proximal to the right atrium (RA) and SVC junction.
- SQ patch: Place the patch along the left mid-axillary, centered over the fourth-to-fifth intercostal space.
- CS lead: Advance the lead tip to just under the left atrial appendage, if possible.

If using a subclavian approach, position the lead laterally to avoid pinching the lead body between the clavicle and the first rib.

⚠ **Warning:** Pinching the lead can damage the lead conductor or insulation, which may cause unwanted high voltage therapies or result in the loss of sensing or pacing therapy.

Using epicardial leads

A variety of surgical approaches can be used to implant epicardial leads, including a limited left thoracotomy or median sternotomy. A typical placement may use an anterior right ventricular patch as the RV (HVB) and a posterolateral left ventricular patch as SVC (HVX).

Follow the general guidelines below for positioning epicardial leads:

- If unipolar epicardial pacing leads are used, position the electrodes about 1 to 2 cm apart to reduce electromagnetic interference, and route the leads together with several loose twists.
- Suture the smooth face of each patch lead against the epicardium or pericardium in locations that produce optimal defibrillation.
- Place the patches so that they encompass the maximum amount of cardiac mass and they have approximately equal amounts of mass between them.
- Ensure that the patches do not overlap and the electrode portions do not touch.
- Avoid placing extra-pericardial patches over the phrenic nerve.

Surgical incisions

A single-incision submuscular or subcutaneous approach is recommended when the ICD is implanted in the pectoral region. Make the implant pocket about 1.5 times the size of the ICD.

Submuscular implant – An incision extending over the deltoid-pectoral groove typically provides access to the cephalic and subclavian veins as well as the implant pocket. Place the ICD sufficiently medial to the humeral head to avoid interference with shoulder motion.

Subcutaneous implant – A transverse incision typically permits isolation of the cephalic vein. Place the ICD far medially to keep the leads away from the axilla. Make sure that the upper edge of the ICD remains inferior to the incision.

Testing sensing and pacing thresholds

Sensing and pacing tests include the following measurements:

- EGM amplitude
- slew rate
- pacing threshold
- pacing lead impedance

Medtronic recommends that you use an 8090 Analyzer lead analysis device to perform sensing and pacing measurements. If you use a Pacing System Analyzer (PSA), perform both atrial and ventricular measurements via the ventricular channel of the PSA.

Refer to the technical manual for the Analyzer you use to find details on performing sensing and pacing measurements.

Parameters

Measured sensing and pacing values must meet the following specific requirements at implant.

Table 4-1. Sensing and pacing values at implant

Measurement	Acute Transvenous Leads	Chronic Leads
R- wave amplitude	≥ 5 mV	≥ 3 mV
P- wave amplitude	≥ 2 mV	≥ 1 mV
Slew rate:		
atrial	≥ 0.5 V/s	≥ 0.3 V/s
ventricular	≥ 0.75 V/s	≥ 0.5 V/s
Capture threshold[a]:		
atrial	≤ 1.5 V	≤ 3.0 V
ventricular	≤ 1.0 V	≤ 3.0 V

[a] At 0.5 ms pulse width

Considerations

When measuring sensing and pacing values, measure between the tip (cathode) and ring or coil (anode) of each bipolar pacing/sensing lead.

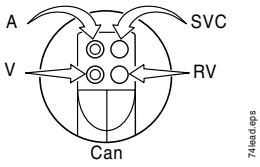
For unipolar epicardial pacing leads, either electrode can be the cathode; use the configuration that yields the lower pacing threshold.

Note: Do not measure the intracardiac EGM telemetered from the ICD to assess sensing.

Connecting the leads to the ICD

For more detailed information about lead/connector compatibility, see the *Marquis DR 7274 Implant Manual*, or contact Medtronic Technical Services at 1-800-723-4636.

Table 4-2. Lead connections



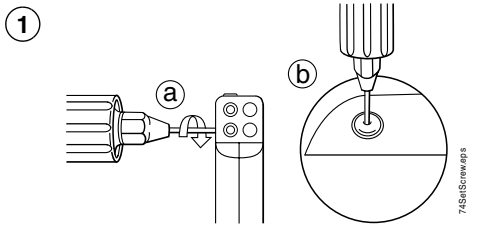
Device Port	Connector Type	Software Name
SVC	DF-1	HVX
RV	DF-1	HVB
Can	n/a	HVA, Can
V	IS-1 bipolar	
A	IS-1 bipolar	

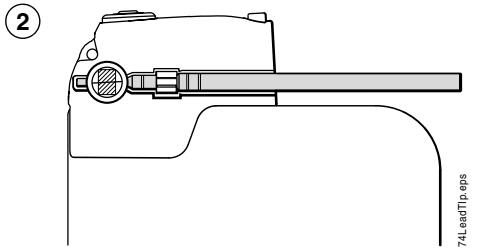
Warning: Loose lead connections may result in inappropriate sensing and failure to deliver necessary arrhythmia therapy.

Caution: Use only the torque wrench supplied with the device. It is designed to prevent damage to the device from overtightening a setscrew.

For easier lead insertion, insert the ventricular IS-1 leg before the other legs.

How to connect the lead to the device





1. Insert the torque wrench into the appropriate setscrew.
   a. If the port is obstructed, retract the setscrew to clear it. Take care not to disengage the setscrew from the connector block.
   b. Leave the torque wrench in the setscrew until the lead is secure. This allows a pathway for venting trapped air when the lead is inserted.
2. Push the lead or plug into the connector port until the lead pin is clearly visible in the pin viewing area. No sealant is required, but sterile water may be used as a lubricant.
3. Tighten the setscrew by turning clockwise until the torque wrench clicks.
4. Tug gently on the lead to confirm a secure fit. Do not pull on the lead until all setscrews have been tightened.
5. Repeat these steps for each lead.

Testing defibrillation operation and effectiveness

To demonstrate reliable defibrillation effectiveness with the implanted lead system, use the ICD to complete one of the following tests:

- Terminate two consecutively induced VF episodes using a delivered energy of 20 joules or less.
- Use the binary search procedure to establish a defibrillation threshold (DFT) of 18 joules or less.

Note: An external defibrillation implant support instrument can also be used to test defibrillation effectiveness. For instructions, see the applicable documentation for the specific support instrument.

High voltage implant values

Measured values must meet the following requirements at implant.

Table 4-3. High voltage therapy values at implant

Measurement	Acute or Chronic Leads
V. Defib impedance	20 - 200 ohms
SVC (HVX) impedance (if applicable)	20 - 200 ohms
Defibrillation threshold	≤ 20 J (two consecutive) or ≤ 18 J (binary search)

⚠ **Warning:** Ensure that an external defibrillator is charged for a rescue shock.

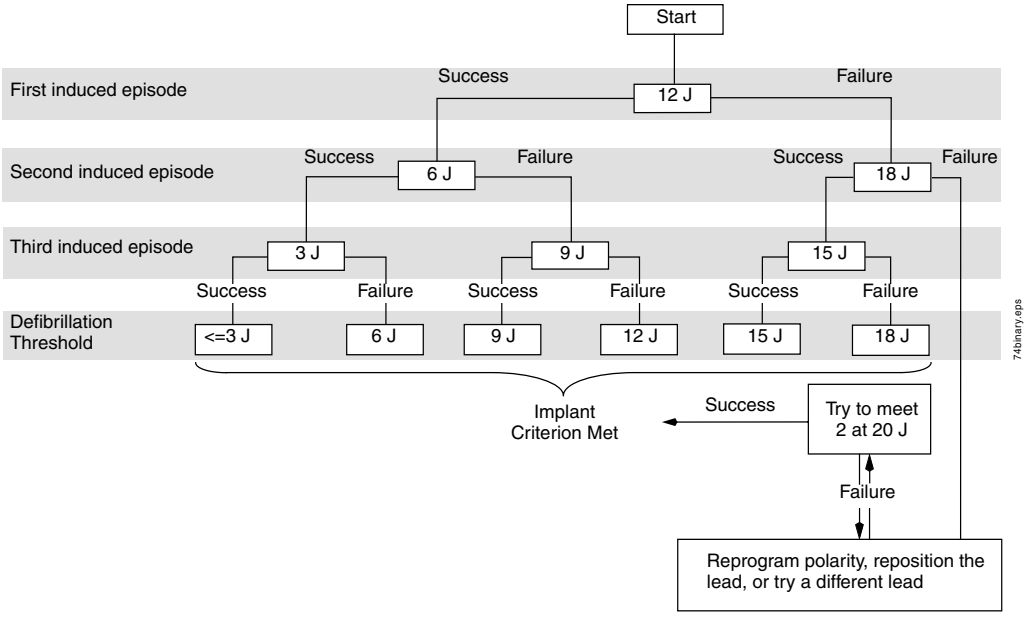
Binary search protocol

By testing defibrillation efficacy at successively lower energy levels, the binary search protocol provides an accurate threshold measurement. However, it generally requires more inductions and more time. Also, cumulative charging of the ICD capacitor affects the device longevity.

For most reliable defibrillation efficacy testing, allow at least five minutes between VF inductions. The ICD software provides an on-screen timer to record elapsed time since the last induction.[1]

If a two-electrode system fails to meet the implant criterion, consider implanting a third electrode and connecting it to the SVC (HVX) port. You can also evaluate the efficacy of ventricular tachycardia and atrial arrhythmia therapies after successfully completing ventricular defibrillation testing.

Figure 4-1. Binary search protocol



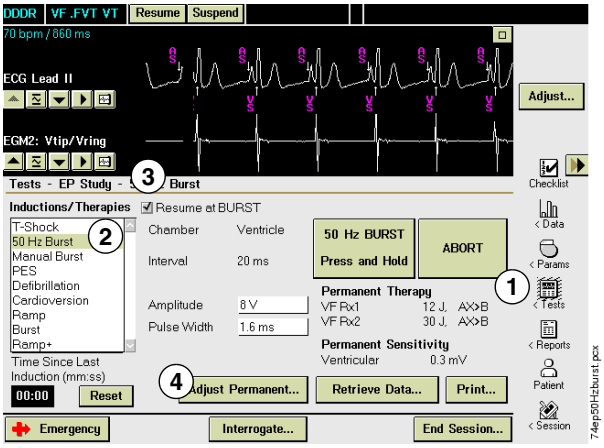
[1] The timer appears on the 50 Hz Burst and T-Shock induction screens.

How to prepare for defibrillation threshold testing

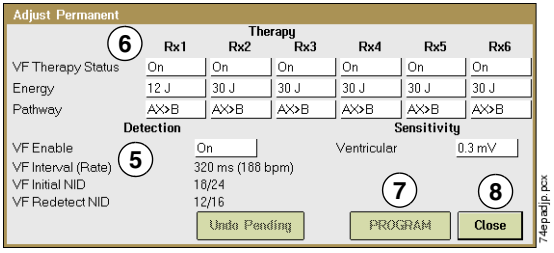
1. Place the programming head over the ICD, start a patient session, and interrogate the device, if you have not already done so.
2. Observe the Marker Channel telemetry annotations and the programmer ECG display to verify that the ICD is sensing properly.
3. Conduct a manual Lead Impedance Test[a] to verify the defibrillation lead connections. Perform this test with the ICD in the surgical pocket and keep the pocket very moist. If the impedance is out of range, perform one or more of the following tasks:
   - Recheck lead connections and electrode placement.
   - Repeat the measurement.
   - Inspect the bipolar EGM for abnormalities.
   - Measure the defibrillation impedance with a manual test shock.
4. Program the ICD or support instrument to properly detect VF with an adequate safety margin (1.2 mV sensitivity).

[a] See “Measuring lead impedance” on page 316.

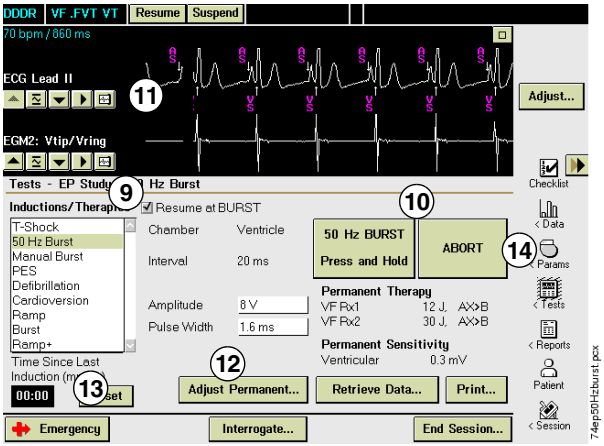
How to perform defibrillation threshold testing



1. Select Tests > EP Study.
2. Select either 50 Hz BURST or T-shock induction.
3. Select [Resume at BURST] or [Resume at DELIVER].
4. Select [Adjust Permanent...].



5. Program VF Enable On.
6. Program the automatic therapy energy settings. Therapies 2-6 should be set to the maximum energy.
7. Select [Program].
8. Select [Close].



9. If performing a T-Shock induction, select the [Enable] checkbox.
10. Select [DELIVER], or [50 Hz BURST Press and Hold].

    If necessary, you can abort an induction or therapy in progress by pressing [ABORT].
11. Observe the live rhythm monitor for proper post-shock sensing.
12. If using the binary search protocol, use the [Adjust Permanent...] button to program the next appropriate energy level (see Figure 4-1).
13. Wait until the on-screen timer reaches 5 minutes, then repeat steps 9 through 12 as needed.
14. Select Params > Detection and program VF, FVT, and VT detection Off before closing.

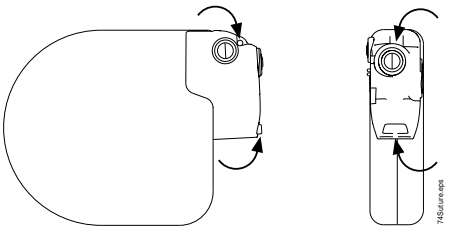
Positioning and securing the ICD

△ **Cautions:** If no SVC electrode is implanted, the pin plug provided with the device must be secured in the SVC port.

Program tachyarrhythmia detection Off before closing.

How to position and secure the device

Suture Hole Locations



1. Ensure that each lead pin or plug is fully inserted into the connector block and that all setscrews are tight.
2. Coil any excess lead length beneath the device. Avoid kinks in the lead conductors.
3. Implant the device within 5 cm of the skin. This position optimizes the ambulatory monitoring operations.
4. Suture the device securely within the pocket to minimize post-implant rotation and migration of the device. Use a surgical needle to penetrate the suture holes.

Completing the implant procedure

After implanting the device, X-ray the patient to verify the device and leads placement. To complete programming the device, select parameters that are appropriate for the patient.

How to complete programming the device

1. After closing the pocket, program detection On. Program ventricular tachyarrhythmia therapies On as desired.
2. Do not enable the Other 1:1 SVTs PR Logic detection criterion until the atrial lead has matured (approximately one month post implant).
3. If external equipment was used to conduct the defibrillation efficacy tests, perform a final VF induction, and allow the implanted system to detect and treat the arrhythmia.
4. Monitor the patient after the implant, and take X-rays as soon as possible to document and assess the location of the leads.
5. Program patient information. See “How to view and enter new patient information” on page 303.
6. Configure the Patient Alert feature. See “Using the Patient Alert feature” on page 253.
7. Set up data collection parameters. See “Setting up data collection” on page 267.
8. Interrogate the device after any spontaneous episodes to evaluate the detection and therapy parameter settings.
9. If the patient has not experienced spontaneous episodes, you may induce the clinical tachyarrhythmias using the non-invasive EP Study features to further assess the performance of the system. See Chapter 14, "Conducting Electrophysiologic Studies" on page 323.
10. Recheck pacing and sensing values, and adjust if necessary.

Conducting a patient follow-up session

5

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Patient follow-up guidelines

Schedule regular patient follow-up sessions to monitor the condition of the ICD and leads and to verify that the ICD is configured appropriately for your patient.

During the first few months after receiving a new device, the patient may require close monitoring. Schedule an office visit at least every three months.

The Quick Look screen, which is displayed after you interrogate the device, provides a good beginning for the follow-up review. Using this screen you can

- verify that the device is functioning correctly.
- review the clinical performance and long term trends.
- print appropriate reports[1] to compare the results to the patient's history and to retain for future reference.

Note: The Checklist feature provides a standard list of tasks to perform at a complete follow-up visit. You can also customize your own checklists if you wish. See "Streamlining follow-ups with Checklist" on page 261 for more information.

Verifying the status of the implanted system

To verify that the ICD and leads are functioning correctly, review the following information from the Quick Look screen and perform follow-up tests as indicated:

- Review the displayed battery voltage for comparison to the Elective Replacement Indicator value (see page 8). Remember that battery voltage may be low if high voltage charging has occurred within 24 hours.
- Review the last full energy charge.
  - For information about adjusting the capacitor formation interval, see "Optimizing charge time" on page 204.
  - If the programmer displays an Excessive Charge Time ERI, the ICD should be replaced immediately.

[1] See "Using Cardiac Compass to view long term clinical trends" on page 294 for information on this new report.

- Review the defibrillation and pacing lead impedance values for inappropriate values or large changes since the last follow-up. See “Measuring lead impedance” on page 316.
- Perform an EGM Amplitude test in each chamber for comparison to previous EGM Amplitude measurements. See “How to perform an EGM Amplitude test” on page 320.
- To review longer term trends in sensing and impedance measurements, select the [>>] button from the lead impedance area of the Quick Look screen. The programmer displays a detailed history of automatic sensing and impedance measurements. See “Taking a quick look at device activity” on page 251.

Verifying accurate detection and appropriate therapy

To verify that the ICD is providing effective tachyarrhythmia detection and therapy, review the following information from the Quick Look screen and investigate as indicated:

- Review Quick Look Observations that relate to patient history and device operation. To display more detailed information about any observation, select the observation and then select the [>>] button.
- Review any Patient alerts listed in the Observations of the Quick Look screen. For the most detailed information about Patient Alerts, select Patient Alert from the Data icon and select [Events].
- Check stored episode records for appropriate sensing and detection of arrhythmias. See “Viewing episode data” on page 280.
- Check stored SVT episode records for appropriate identification of SVTs.

Considerations

Review the following information before verifying detection and therapy.

Flashback memory – In addition to the episode text and stored electrograms, use Flashback memory and interval plots to help investigate the accuracy and specificity of ventricular detection.

Episode misidentification – If the episode records indicate that false detections have occurred, the Sensing Integrity counter may help in determining the prevalence of oversensing. For more information, see “Sensing integrity counter” on page 275.

If the ICD is oversensing, consider these programming options:

- Increase the Pace Blanking value.
- Increase the sensitivity threshold.

△ **Caution:** Do not re-program the ICD to decrease oversensing without assuring that appropriate sensing is maintained. See “Setting up sensing” on page 61.

If the episode records reveal that a stable monomorphic VT has been identified and treated as VF, consider these options to improve the detection accuracy:

- Review the Interval Plot for the episode, and adjust VF Interval, if necessary. Use caution when reprogramming the VF Interval, because changes to this value can adversely affect VF detection.
- Consider enabling FVT via VF detection. See “Detecting FVT episodes” on page 76.

If the SVT episode records include episodes of true VT, review the SVT episode record to identify the SVT detection criterion that withheld detection. Adjust the SVT detection criteria parameters as necessary. See “Enhancing detection with PR Logic criteria” on page 88, and “Enhancing VT detection with the Stability criterion” on page 97.

Verifying effective bradycardia pacing

To verify that the ICD is sensing and pacing appropriately, review the following information from the Quick Look screen and investigate as indicated:

- Confirm that the patient is receiving adequate cardiac support for daily living activities.
- Review the pacing conduction history for comparison to the patient history. A sharp increase in the paced beats percentage may indicate a need for investigation and analysis.

- Review the recorded Mode Switch episodes for comparison to the patient's atrial arrhythmia history. A dramatic increase in frequency or duration of atrial episodes may indicate a need for investigation and analysis.

  To display more detailed information about the Mode Switch episodes, perform these steps: select Episodes and Counters from the Data icon; select the Mode Switch episodes from the listed episode counters; then select the [Open Data] button.
- Review the Cardiac Compass report for comparison to patient history (see page 294).
- Conduct pacing threshold tests (see page 313) to verify that the programmed pacing outputs provide a sufficient safety margin.

Considerations

Review the following information before verifying bradycardia pacing.

Atrial Pacing – If the conduction history shows a predominance of atrial pacing despite a healthy sinus response, consider these options to decrease the atrial pacing burden:

- Decrease the Lower Rate.
- Decrease the rate response or increase the activity threshold.

Ventricular Pacing – If the ventricle is predominantly paced and the patient exhibits adequate ventricular response, consider these options:

- Decrease the Lower Rate.
- Increase the AV delays.

Conduction History – If the reported percentages in the conduction history do not add up to 100, the percentages may be rounded. Frequent premature contractions or A:V dissociation may also be the cause. Consider any of the following options:

- Program the pacing mode to DDD or DDDR to promote A-V synchrony. (If appropriate, enable Mode Switch to keep the benefits of DDIR pacing during atrial high rate episodes.)
- Enable Ventricular Rate Stabilization to smooth the heart rate following premature ventricular beats.

Part III

Configuring the ICD for the patient

Detecting tachyarrhythmias

6

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Detection overview

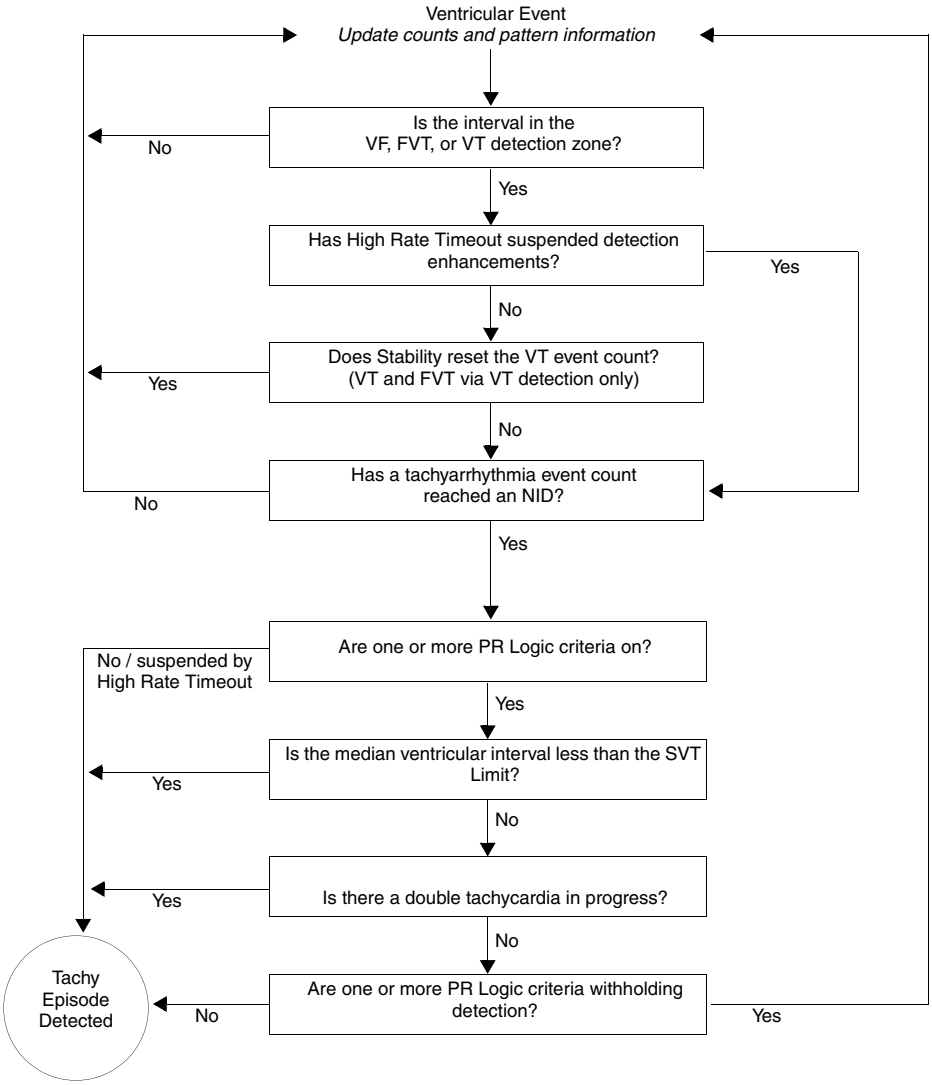
The device detects ventricular tachyarrhythmias (VF, VT, and FVT) by comparing the time intervals between sensed ventricular events to a set of programmable detection intervals. If enough intervals occur that are shorter than the programmed intervals, the device detects a tachyarrhythmia, and responds automatically with a programmed therapy. After delivering the therapy, the device either redetects the arrhythmia and delivers the next programmed therapy or detects episode termination.

To avoid detecting rapidly conducted SVTs (for example, sinus tachycardia or atrial fibrillation) as ventricular tachyarrhythmias, the device provides several detection enhancements, including PR Logic and Stability detection criteria.

Figure 6-1 shows how all of these detection features interact during initial detection. During redetection, the device does not apply the PR Logic detection criteria.

Note: Detection functions can be turned off by programming the VF Enable, FVT Enable, and VT Enable parameters to Off. For an example, see “How to program VF detection” on page 68.

Figure 6-1. How detection features interact during initial detection



Suspending tachyarrhythmia detection

When detection is suspended, the device temporarily stops classifying and counting tachyarrhythmia intervals. Sensing and bradycardia pacing remain active, and the programmed detection settings are not modified.

Detection is suspended

- when the device senses the presence of a strong magnet. The programmer head contains a magnet which suspends detection, but once telemetry between the device and programmer is established, detection resumes.
- while performing any of the manual system tests, including Underlying Rhythm, Pacing Threshold, Lead Impedance, EGM Amplitude, and Charge/Dump. Detection automatically resumes once the test is complete.
- while performing a T-Shock, 50 Hz Burst, Manual Burst, or PES Induction. You can choose to have the device automatically resume detection after delivering the induction.
- when you deliver a Manual or Emergency therapy. You can resume detection by selecting the [Resume] button or removing the programming head from the device.
- when you select the on-screen [Suspend] button. You can resume detection by selecting the [Resume] button or by removing the programming head from the device.
- during the automatic daily lead impedance measurements. Detection resumes when the measurements are complete.
- while the device is delivering an automatic tachyarrhythmia therapy (including capacitor charging for defibrillation and cardioversion). However, the device does continue to confirm the detected episode during charging. Detection resumes when the therapy is complete.

  Note: The device suspends VT detection (and Combined Count detection; see page 81) for 17 events following a defibrillation therapy delivered in response to a detected VF.[1]
- during charging for Automatic Capacitor Formation. Detection resumes when charging is complete.

[1] If the defibrillation therapy is delivered as a result of a High Rate Timeout Therapy operation, VT detection is not suspended (see page 103).

Setting up sensing

The device provides bipolar sensing in both the atrium and ventricle via the sensing electrodes of the implanted atrial and ventricular leads. You can adjust the sensitivity to intracardiac signals using independent atrial and ventricular sensitivity settings. These settings define the minimum electrical amplitude recognized by the device as an atrial or ventricular sensed event.

Proper sensing is essential for the safe and effective use of the device. To provide appropriate sensing, the device uses:

- auto-adjusting atrial and ventricular sensing thresholds
- short (30 ms) cross-chamber blanking after paced events
- no cross-chamber blanking after sensed events

See details about sensing on page 64.

Parameters

	* Medtronic nominal setting
V. Sensitivity (mV) – Minimum amplitude of electrical signal that registers as a sensed ventricular event.	0.15, 0.3*, 0.45, 0.6, 0.9, 1.2
A. Sensitivity (mV) – Minimum amplitude of electrical signal that registers as a sensed atrial event.	0.15, 0.3*, 0.45, 0.6, 0.9, 1.2, 1.5, 2.1

Considerations

Review the following information before programming sensing parameters.

Dual chamber sensing and bradycardia pacing modes – The device senses in both the atrium and the ventricle at all times, except when the programmed bradycardia pacing mode is DOO or VOO. When the pacing mode is programmed to DOO or VOO mode, there is no sensing in the ventricle. In order to program either DOO or VOO mode, you must first disable detection.

Sensitivity thresholds – The programmed atrial and ventricular sensitivity thresholds apply to all features related to sensing, including detection and bradycardia pacing.

Bradycardia pacing and sensing – A combination of high pacing pulse width or high amplitude with a low sensitivity threshold may cause inappropriate sensing across chambers or in the same chamber. Programming a lower pulse width, lower amplitude, longer pace blanking, or a higher sensitivity threshold may eliminate this inappropriate sensing.

Recommended ventricular sensitivity threshold – A ventricular sensitivity threshold of 0.3 mV is recommended to maximize the probability of detecting VF and to limit the possibility of oversensing and cross-chamber sensing.

High ventricular sensitivity threshold – Setting V. Sensitivity to a value greater than 0.6 mV is not recommended except for testing. Doing this may cause undersensing, which can cause any of the following situations:

- delayed or aborted cardioversion therapy
- delayed defibrillation therapy (when VF confirmation is active)
- asynchronous pacing
- underdetection of tachyarrhythmias

Low ventricular sensitivity threshold – If you set V. Sensitivity to its most sensitive value of 0.15 mV, the device will be more susceptible to EMI, cross-chamber sensing, and oversensing.

Recommended atrial sensitivity threshold – An atrial sensitivity threshold of 0.3 mV is recommended to optimize the effectiveness of PR Logic detection criteria and atrial pacing operations, while limiting the possibility of oversensing and cross-chamber sensing.

High atrial sensitivity threshold – If you set the A. Sensitivity value too high, the device may not provide reliable sensing of P-waves during SVTs and sinus rhythm.

Low atrial sensitivity threshold – If you set the A. Sensitivity value to its most sensitive value of 0.15 mV, the device will be more susceptible to EMI, far-field R-wave sensing, and oversensing.

Testing sensitivity after reprogramming – If you change the ventricular sensitivity threshold, evaluate for proper sensing and detection by inducing VF and allowing the device to automatically detect and treat the arrhythmia.

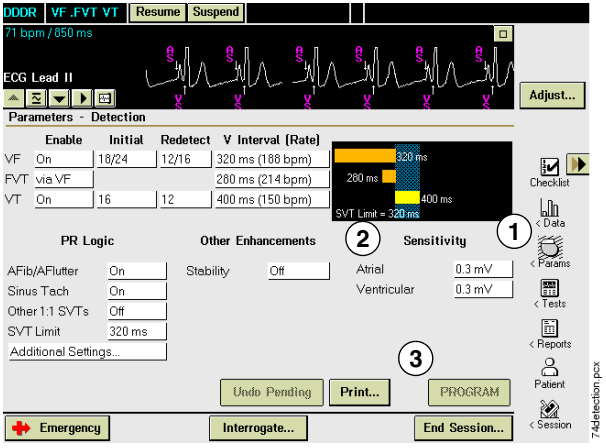
Atrial pacing and ventricular sensing – If you program the device to an atrial pacing mode, make sure that it does not sense atrial pacing pulses as ventricular events.

Sensing during VF – Always verify that the device senses properly during VF. If the device is not sensing or detecting properly, program detection and therapies off, and evaluate the system (making sure to monitor the patient for life-threatening arrhythmias until you enable detection and therapies again). You may need to reposition or replace the ventricular sensing lead to achieve proper sensing.

Atrial lead selection – Atrial leads with minimal tip-to-ring spacing may reduce far-field R-wave sensing.

Repositioning the atrial lead – You may need to reposition or replace the atrial sensing lead if reprogramming the atrial sensitivity threshold does not provide reliable atrial sensing during SVTs and sinus rhythm.

How to program sensitivity



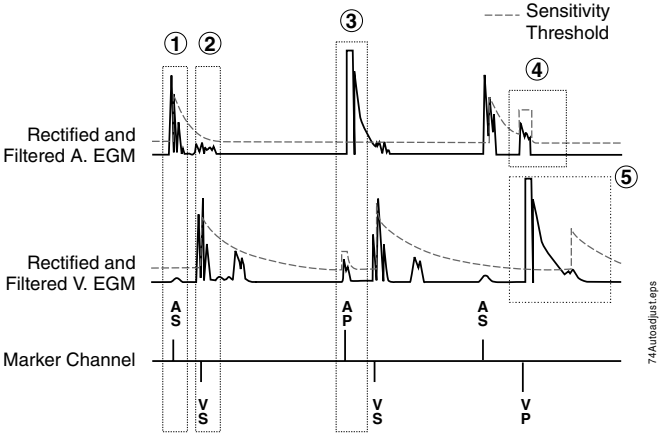
1. Select Params > Detection.
2. Select the desired A. Sensitivity and V. Sensitivity parameters.
3. Select [PROGRAM].

Details about sensing

Auto-adjusting sensitivity thresholds

The device automatically adjusts the sensitivity thresholds after certain paced and sensed events to help reduce oversensing from T-waves, cross-chamber events, and pacing. Figure 6-2 shows how sensitivity thresholds are adjusted after different types of events.

Figure 6-2. Auto-adjusting sensitivity thresholds



1 After an atrial sensed event, the atrial sensitivity threshold increases to 75% of the EGM peak (maximum: 8x the programmed value, decay constant: 200 ms).

2 After a ventricular sensed event, the ventricular sensitivity threshold increases to 75% of the EGM peak (maximum: 8x the programmed value, decay constant: 450 ms).[a]

3 After an atrial paced event, the device does not adjust the atrial sensitivity threshold. The ventricular sensitivity threshold increases by 0.45 mV (decay constant: 60 ms).[b]

4 After a ventricular paced event, the atrial sensitivity threshold increases to 4x the programmed value (maximum: 1.8 mV, immediate return after 60 ms).[b]

5 After the ventricular pace blanking period is finished, the ventricular threshold increases to 4.5x the programmed value (maximum: 1.8 mV, decay constant: 450 ms).

[a] The exponential decay continues through a subsequent ventricular pacing pulse and its blanking period.

[b] If the programmed sensitivity value exceeds 0.3 mV (ventricular) or 1.2 mV (atrial), the threshold is not adjusted.

Blanking periods

During a blanking period, the device does not sense electrical signals. This helps prevent sensing of device pacing, cardioversion and defibrillation pulses, post-pacing depolarization, T-waves, and multiple sensing of the same event. The blanking periods following paced events are longer than those following sensed events to avoid sensing the atrial and ventricular depolarizations.

Notes:

- To enhance sensing and detection during tachyarrhythmias, the device does not apply cross-chamber blanking (blank sensing in the opposite chamber) after a sensed event.
- Atrial sensing is still active during the Post-Ventricular Atrial Blanking (PVAB) period (see “Post-Ventricular Atrial Blanking Period” on page 160).

Table 6-1 shows the duration of the fixed blanking periods. For information on programmable pace blanking periods, see page 148.

Table 6-1. Fixed blanking periods

Cross-chamber blanking after atrial or ventricular pacing pulse	30 ms
Atrial blanking after sensed atrial event	100 ms
Ventricular blanking after sensed ventricular event	120 ms
Atrial and ventricular blanking after delivered cardioversion or defibrillation therapy	520 ms

Refractory periods

During a refractory period, the device senses normally, but classifies sensed events as refractory and limits its response to these events. Pacing refractory periods prevent inappropriately sensed signals, such as far-field R-waves (ventricular events sensed in the atrium) or electrical noise, from triggering certain pacing timing intervals.

Synchronization refractory periods help prevent the device from delivering cardioversion and defibrillation therapies at inappropriate times. See “Synchronizing defibrillation without confirming VF” on page 114 and “Synchronizing cardioversion after charging” on page 135.

Note: Refractory periods do not affect tachyarrhythmia detection.

Detecting VF episodes

The device detects VF episodes by examining the cardiac rhythm for short ventricular intervals. If a predetermined number of intervals occurs that are short enough to be considered VF events, the device detects VF and delivers the first programmed VF therapy. After therapy, the device continues to evaluate the ventricular rhythm to determine if the episode is ongoing.

See details about VF detection on page 68.

Parameters

* Medtronic nominal setting

VF Detection Enable – Turns VF detection on or off.	On*, Off
VF Interval (ms) – V-V intervals shorter than this value are counted as VF events.	240, 250, . . ., 320*, . . .,400
VF Initial NID – Number of Intervals to Detect: number of VF events the device must count to detect a VF episode.	12/16, 18/24*, 24/32, 30/40, 45/60, 60/80, 75/100, 90/120, 105/140, 120/160
VF Redetect NID – Number of Intervals to Redetect: number of VF events the device must count to redetect a continuing VF after a therapy.	6/8, 9/12, 12/16*, 18/24, 21/28, 24/32, 27/36, 30/40

Considerations

Review the following information before programming VF Detection parameters.

VF Interval minimum setting – To ensure proper VF detection, you should not program the VF Interval less than 300 ms.

VF Interval maximum setting – Programming the VF Interval to a value greater than 350 ms may cause inappropriate detection of rapidly conducted atrial fibrillation as VF or FVT via VF. Intervals shorter than the VF Interval are counted using the VF event counter, which is more sensitive than the consecutive VT event counter.

VF, FVT, and VT Intervals – To allow for normal variations in the patient's tachycardia interval, you should program the VF, FVT, and VT intervals at least 40 ms apart.

Episode redetection – You can expedite redetection by programming the VF and VT Redetect NIDs lower than the Initial NIDs.

Enabling VF detection – When VF Detection Enable is programmed On for the first time, the device

- enables Automatic Capacitor Formation
- starts recording Cardiac Compass data
- starts recording lead performance trends (starting at 3:00 AM, by the device clock)
- clears all brady pacing counters

VF detection and PR Logic criteria – You can program the device to exclude rapidly conducted SVTs from VF Detection by enabling the PR Logic detection criteria. Note that the SVT Limit must be programmed shorter than the VF Interval in order for the PR Logic criteria to affect VF detection. See "Enhancing detection with PR Logic criteria" on page 88.

Double tachycardia detection – When any PR Logic detection criteria are enabled, the device also enables double tachycardia detection (VF, VT, or FVT in the presence of an SVT). See "Detecting double tachycardias" on page 100.

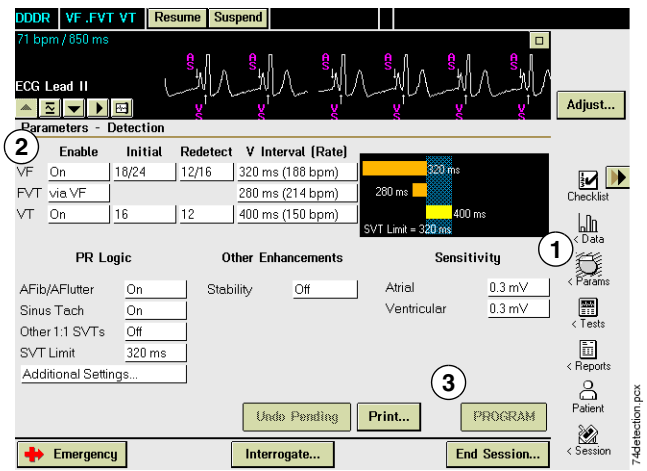
Restrictions

Review the following information before programming VF Detection parameters.

Tachyarrhythmia detection and bradycardia pacing – To ensure reliable ventricular tachyarrhythmia detection, the programmer regulates the values available for bradycardia pacing and tachyarrhythmia detection. See “Parameter interlocks” on page 386.

VF detection backup – To ensure VF Detection backup during VT and FVT episodes, if VF Detection is off, both VT Detection and FVT Detection must also be off.

How to program VF detection



To program VF detection:

1. Select Params > Detection.
2. Select the desired values for VF Enable, VF Initial NID, VF Redetect NID, and VF Interval.
3. Select [PROGRAM].

Details about VF detection

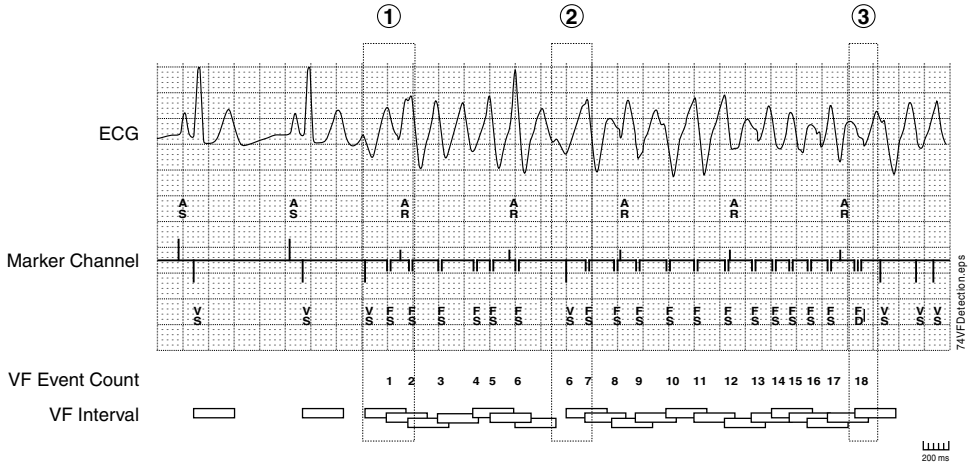
The device detects VF by counting the number of VF events, which are V-V intervals shorter than the programmed VF Interval. On each event, the device counts the number of recent VF events. The number of recent events examined is called the VF detection window. The size of the VF detection window is the second number in the programmed VF NID (for example, 24 events if the VF Initial NID is 18/24).

The threshold for detecting VF is the first number in the programmed VF NID (for example, 18 events if the VF Initial NID is 18/24). This threshold is always 75% of the VF detection window. That is, if 75% of the events in the VF detection window are VF events, the device detects a VF episode (see Figure 6-3).

After the device detects VF, it delivers the first programmed VF therapy. Following the therapy, if the number of VF events reaches the programmed VF Redetect NID, the device redetects VF and delivers the next programmed VF therapy.

Note: The device can also detect VF Episodes via the Combined Count detection criterion (see page 81).

Figure 6-3. Device detects VF



1 VF starts, and the device begins counting VF events (intervals less than the programmed VF Interval).

2 A ventricular interval occurs outside the VF detection zone. The VF event count is not incremented.

3 The VF event count reaches the programmed VF NID value of 18 events out of 24, and the device detects VF.

Detecting VT episodes

The device detects VT episodes by examining the cardiac rhythm for short ventricular intervals. If enough intervals occur that are short enough to be considered VT events (but are not VF or FVT events), the device detects VT and delivers the first programmed VT therapy. After therapy, the device continues to evaluate the ventricular rhythm to determine if the episode is ongoing.

You can program the device to detect and record VT episodes without treating them with VT therapies by setting VT Detection Enable to Monitor. If a patient's VT episodes are well-tolerated, this feature allows you to collect data about these episodes without delivering therapy or affecting VF detection.

See details about VT detection on page 72.

Parameters

* Medtronic nominal setting

VT Detection Enable – Turns VT detection on or off, or enables VT monitoring.	On, Off*, or Monitor
VT Interval (Rate) (ms) – V-V intervals shorter than this value are counted as VT events.	280, 290, . . ., 400*, . . ., 600
VT Initial NID – Number of Intervals to Detect: number of VT events the device must count to detect a VT episode.	12, 16*, . . ., 52, 76, 100
VT Redetect NID – Number of Intervals to Redetect: number of VT events the device must count to redetect a continuing VT after a therapy.	4, 8, 12*, . . ., 52

Considerations

Review the following information before programming VT Detection parameters.

VF, FVT, and VT Intervals – To allow for normal variations in the patient's tachycardia interval, you should program the VF, FVT, and VT intervals at least 40 ms apart.

Episode redetection – You can expedite redetection by programming the VF and VT Redetect NIDs lower than the Initial NIDs.

VT Detection Enable, AFib/AFlutter, and Sinus Tach – When you set VT Detection Enable to On or Monitor, the AFib/AFlutter and Sinus Tach parameters are also automatically set to On.

VT detection and Combined Count detection – When VT Detection is On, the device applies the Combined Count detection criterion to help speed detection of rhythms that fluctuate between detection zones. Combined Count detection is disabled if VT Detection is set to Off or Monitor. See “Detecting tachyarrhythmia episodes with Combined Count” on page 81.

VT detection and rapidly conducted SVTs – You can program the device to exclude rapidly conducted SVTs from VT detection by enabling the PR Logic or Stability detection criteria. See “Enhancing VT detection with the Stability criterion” on page 97, and “Enhancing detection with PR Logic criteria” on page 88.

Double tachycardia detection – When any PR Logic detection criteria are enabled, the device also enables double tachycardia detection (VF, VT, or FVT in the presence of an SVT; see page 100).

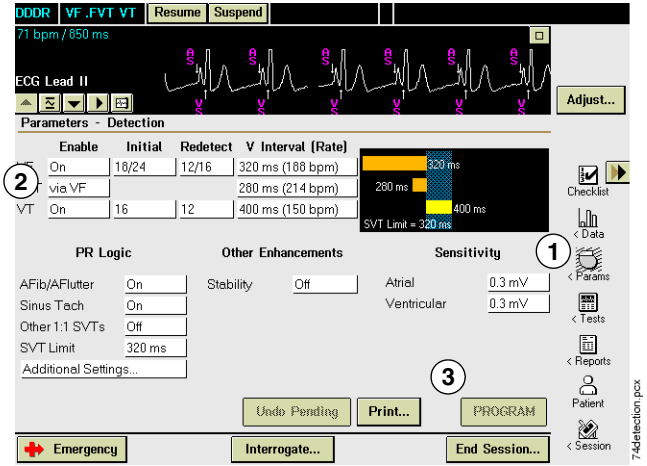
Restrictions

Review the following information before programming VT detection parameters.

Tachyarrhythmia detection and bradycardia pacing – To ensure reliable ventricular tachyarrhythmia detection, the programmer regulates the values available for bradycardia pacing and tachyarrhythmia detection. See “Parameter interlocks” on page 386.

VF detection backup – To ensure VF detection backup during VT and FVT episodes, if VF Detection is off, both VT Detection and FVT Detection must also be off.

How to program VT detection



To program VT detection:

1. Select Params > Detection.
2. Select the desired values for VT Enable, VT Initial NID, VT Redetect NID, and VT Interval.
3. Select [PROGRAM].

Details about VT detection

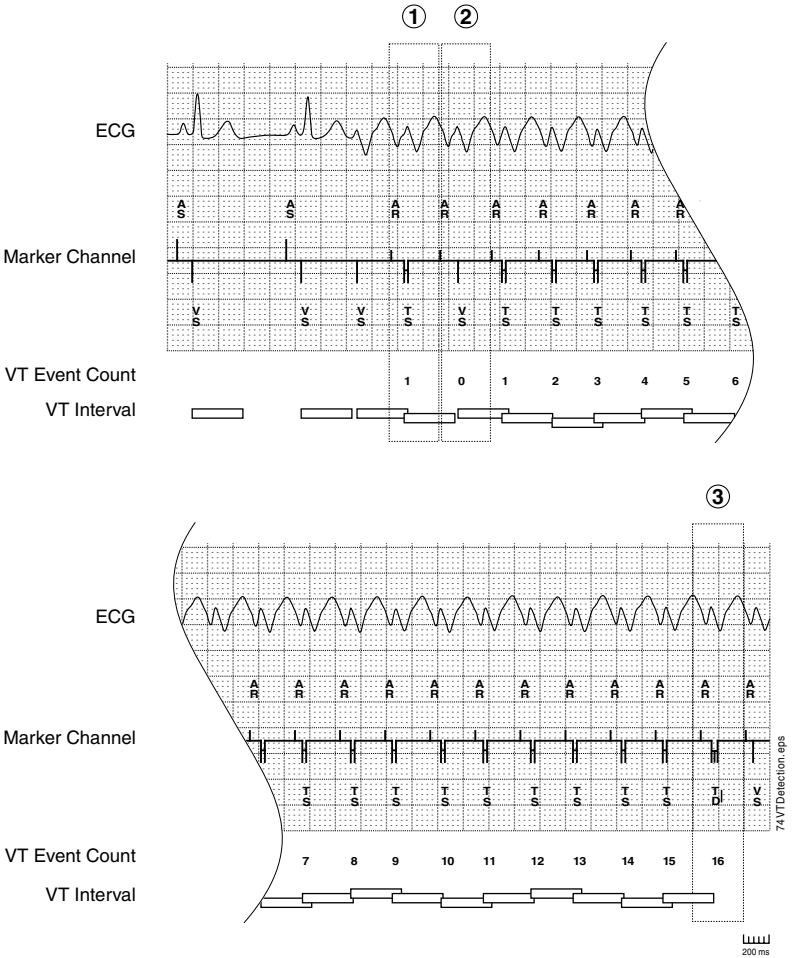
The device detects VT by counting the number of consecutive VT events. A VT event is a V-V interval shorter than the programmed VT Interval but greater than or equal to the VF Interval. If the number of consecutive VT events reaches the programmed VT Initial NID, the device detects VT (see Figure 6-4).

The VT event count resets to zero whenever an interval occurs that is greater than or equal to the programmed VT Interval. The count remains at the current value if an interval is shorter than the programmed VF Interval.

After the device detects VT, it delivers the first programmed VT therapy. Following the therapy, if the VT event counter reaches the VT Redetect NID, the device redetects VT and delivers the next programmed therapy.

Note: The device can also detect VT Episodes via the Combined Count detection criterion (see page 81).

Figure 6-4. Device detects VT



1 VT starts, and the device begins counting VT events (intervals less than the programmed VT Interval, but greater than or equal to the VF Interval).

2 A ventricular interval occurs outside VT detection zone. The VT event count resets to zero.

3 The VT event count reaches the programmed VT NID of 16 events, and the device detects VT.

VT monitoring

You can program the device to record VT episodes without delivering VT therapy by setting VT Detection to Monitor. When VT monitoring is enabled, the device detects VT episodes but does not deliver VT therapy (see Figure 6-5). Instead, it records VT episodes, labeling them as “monitored,” and waits for episode termination to occur.

When VT Detection is set to Monitor, several detection operations work differently.

VT event counting – Before the device detects an episode, it counts VT events normally. However, once the VT Initial NID is reached, the device sets the VT event count to zero and suspends VT event counting for the rest of the episode.

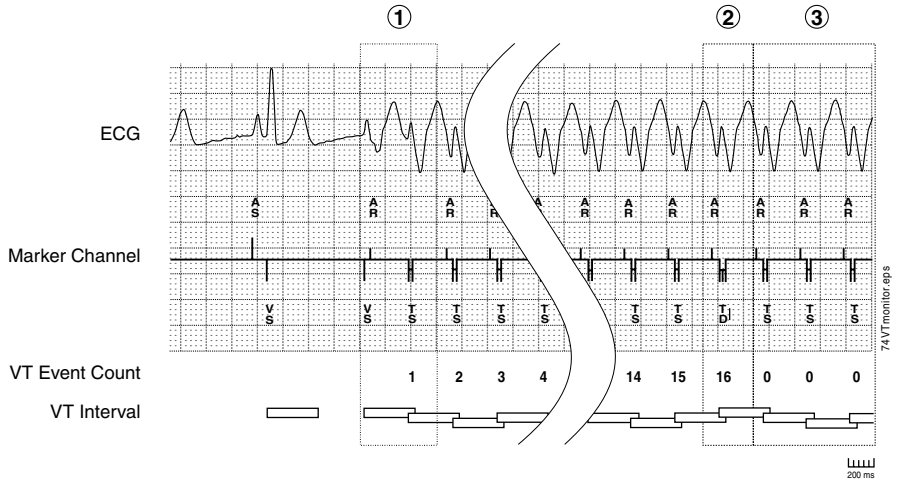
VF and FVT detection – VF and FVT detection operate as if VT detection is off. Specifically, Combined Count detection is disabled, and FVT via VT detection is not selectable. If a monitored VT episode accelerates into the FVT or VF detection zone, the device applies the VF Initial NID to detect the new tachyarrhythmia. Once an episode is in progress, VT event counting doesn’t resume until the episode ends.

△ **Caution:** Programming the VF Interval greater than 350 ms may result in inappropriate detection of rapidly conducted atrial fibrillation as VF or FVT via VF. Intervals shorter than the VF Interval are counted using the VF event counter, which is more sensitive than the consecutive VT event counter.

PR Logic and Stability criteria – Before the device detects a tachyarrhythmia episode, the PR Logic and Stability criteria, if turned on, are applied. If a monitored VT episode accelerates into the FVT or VF detection zone, the device continues to apply PR Logic criteria as initial VF or FVT detection begins. However, because the Stability feature does not affect VF detection or FVT via VF detection, it is not applied.

Episode termination – The device compares ventricular intervals to the VT Interval to identify when a VT monitored episode has ended. However, if a VF episode or FVT via VF episode occurs when VT monitoring is enabled, the device compares ventricular intervals to the VF Interval to identify episode termination.

Figure 6-5. Device detects and monitors VT



1 VT starts, and the device begins counting VT events (intervals less than the programmed VT Interval but greater than or equal to the VF Interval).

2 The VT event count reaches the programmed VT NID of 16 events, and the device detects VT.

3 After detecting the VT episode, the device resets the VT event count to zero and monitors the episode until termination.

Detecting FVT episodes

The device detects episodes of Fast Ventricular Tachycardia (FVT) by examining the cardiac rhythm for short ventricular intervals. If enough intervals occur in the programmed FVT detection zone, the device detects FVT and delivers the first programmed FVT therapy. After therapy, the device continues to evaluate the ventricular rhythm to determine if the episode is ongoing. To make sure it delivers sufficiently aggressive therapies, the device can merge the programmed detection zones during redetection to increase sensitivity.

See details about FVT detection on page 78.

Parameters

* Medtronic nominal setting

FVT Detection Enable – Enables FVT detection via the VF or the VT detection algorithm.	Off*, via VF, or via VT
FVT Interval (Rate) (ms) – V-V intervals between this value and the programmed VF Interval are marked as FVT events.	200, 210, . . ., 600

Considerations

Review the following information before programming FVT Detection parameters.

VF, FVT, and VT Intervals – To allow for normal variations in the patient's tachycardia interval, you should program the VF, FVT, and VT intervals at least 40 ms apart.

Episode redetection – You can expedite redetection by programming the VF and VT Redetect NIDs lower than the Initial NIDs.

FVT detection enable – Your choice for an appropriate setting for FVT Detection should depend on the patient's VF and VT cycle lengths. After determining a reliably sensitive VF Interval, consider the following suggestions:

- If the patient presents with a clinical VT interval in the VF zone, select via VF to ensure reliable detection of VF. (VT Detection need not be enabled at all.)
- If the patient presents with two clinical VTs, both outside the VF zone, select via VT to allow for correct classification of the faster VT and to offer a separate therapy regimen for each VT.
- If the patient presents with only one clinical VT which is outside the VF zone, select VF and VT Detection only, and set FVT Enable to Off.

FVT detection and PR Logic criteria – You can program the device to exclude rapidly conducted SVTs from FVT Detection by enabling the PR Logic detection criteria. Note that the SVT Limit must be programmed shorter than the VF Interval for the PR Logic criteria to affect FVT via VF detection.

Double tachycardia detection – When any PR Logic detection criteria is enabled, the device also enables double tachycardia detection (VF, VT, or FVT in the presence of an SVT, see page 100).

Restrictions

Review the following information before programming FVT Detection parameters.

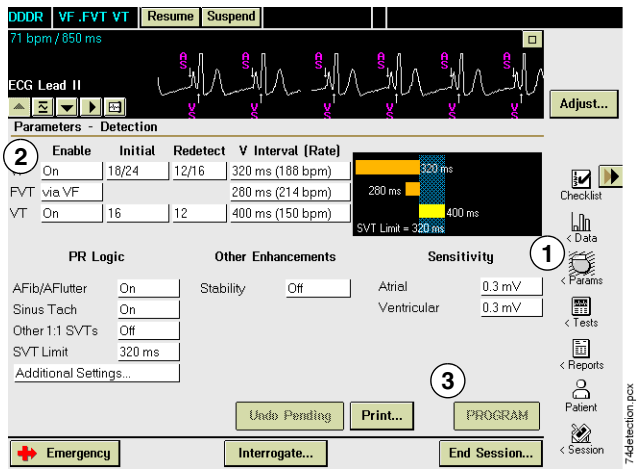
Tachyarrhythmia detection and bradycardia pacing – To ensure reliable ventricular tachyarrhythmia detection, the programmer regulates the values available for bradycardia pacing and tachyarrhythmia detection. See “Parameter interlocks” on page 386.

VF detection backup – To ensure VF Detection backup during VT and FVT episodes, VT and FVT Detection cannot be on unless VF Detection is also on.

FVT detection – To ensure reliable ventricular tachyarrhythmia detection, the programmer regulates the values available for the FVT parameter as follows:

- VT Detection must be set to On if FVT Detection is set to via VT.
- If FVT Detection is set to via VF, the FVT Interval must be programmed to a value shorter than the VF Interval.
- If FVT Detection is set to via VT, the FVT Interval must be programmed to a value greater than the VF Interval and less than or equal to the VT Interval.

How to program FVT detection



To program FVT detection:

1. Select Params > Detection.
2. Select the desired values for FVT Enable and FVT Interval.
3. Select [PROGRAM].

Details about FVT detection

You can program the device to detect FVT episodes via the VF or VT detection zone and NID.

When FVT Detection is set to via VF, a V-V interval within the FVT detection zone is marked as an “FVT via VF” event. When the VF NID is reached, the device reviews the last eight intervals:

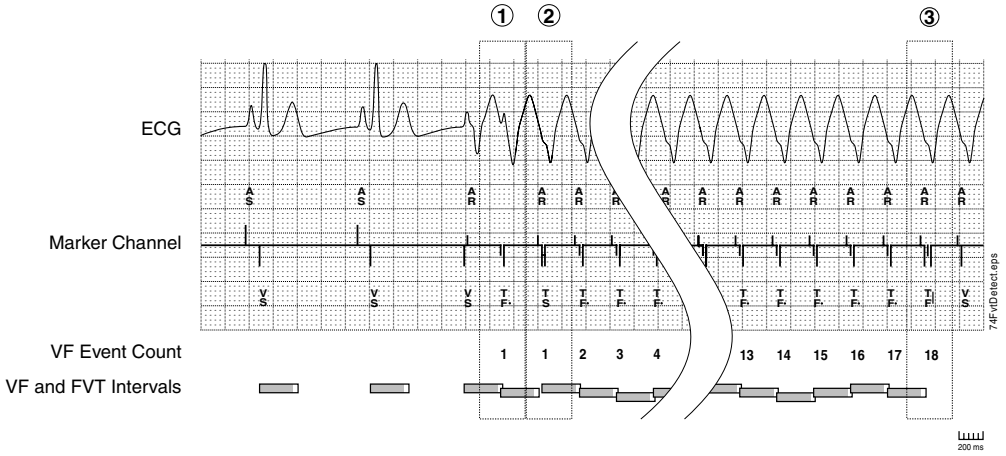
- If any of the last eight intervals are in the VF zone, it detects the episode as VF.
- If all of the last eight intervals are outside the VF zone, it detects the episode as FVT (see Figure 6-6).

When FVT Detection is set to via VT, a V-V interval within the FVT detection zone is marked as an “FVT via VT” event. When the VT NID is reached, the device reviews the last eight intervals:

- If any of the last eight intervals are in the VF or FVT zones, it detects the episode as FVT.
- If all of the last eight intervals are outside the FVT and VF zones, it detects the episode as VT.

Note: The device can also detect FVT episodes via the Combined Count detection criterion (see page 81).

Figure 6-6. Device detects FVT via VF



1 A fast ventricular tachycardia starts, and the first event falls into the FVT detection zone.

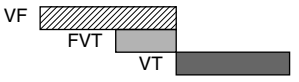
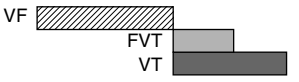
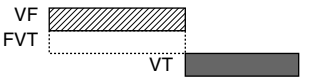
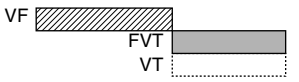
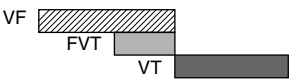
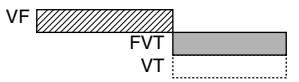
2 The second event of the FVT episode has an interval that falls into the VT zone. The VF event count is not incremented.

3 The device detects FVT after the VF event count reaches the VF Initial NID.

Zone merging after detection

To ensure the device delivers sufficiently aggressive therapies during an extended or highly variable tachyarrhythmia episode, the device merges detection zones during redetection in some instances, as shown in Figure 6-7. The merged zone configuration uses the event counting and therapies for the faster arrhythmia and remains in effect until episode termination.

Figure 6-7. FVT zone merging

	FVT set to "via VF"	**FVT set to "via VT"**
Before detection:		
After VF detection:	VF and FVT zones merge, leaving a larger VF zone. 	VT and FVT zones merge, leaving a larger FVT zone. 
After FVT detection:	All zones remain unchanged. 	VT and FVT zones merge, leaving a larger FVT zone. 
	Detection Intervals: VF Interval: 320 ms, FVT Interval: 280 ms / 360 ms , VT Interval: 400 ms	

Detecting tachyarrhythmia episodes with Combined Count

Because the device counts VF and VT events separately, rhythms with variable cycle lengths can cause both event counts to increment during an episode. To prevent these rhythms from delaying detection, the device automatically enables the Combined Count detection criterion if both VF and VT detection are programmed On.

The Combined Count criterion compares the sum of the VF and VT event counts to the Combined Number of Intervals to Detect (CNID), which the device calculates automatically from the programmed VF NID values. If the CNID is met, the device reviews the recent intervals to determine if the episode should be treated as a VF, FVT, or VT episode. The Combined Count criterion applies during both initial detection and redetection.

Details about Combined Count detection

The Combined Count detection algorithm expedites detection or redetection of ventricular tachyarrhythmias with ventricular intervals that fluctuate between the VF and VT detection zones. When VT detection is on, the device applies Combined Count detection, which tracks the combined number of VT and VF events counted. If this sum reaches the Combined Number of Intervals to Detect (CNID), the device detects VF, FVT, or VT. Combined Count detection also applies to redetected episodes.

Note: Combined Count detection is off when VT detection is set to Monitor or Off.

If the VF event counter reaches six, the device automatically applies the Combined Number of Intervals to Detect (CNID). The CNID is calculated by multiplying the current VF NID (Initial or Redetect) by 7/6 and rounding down. Table 6-2 shows the CNID values that correspond to each VF NID value.

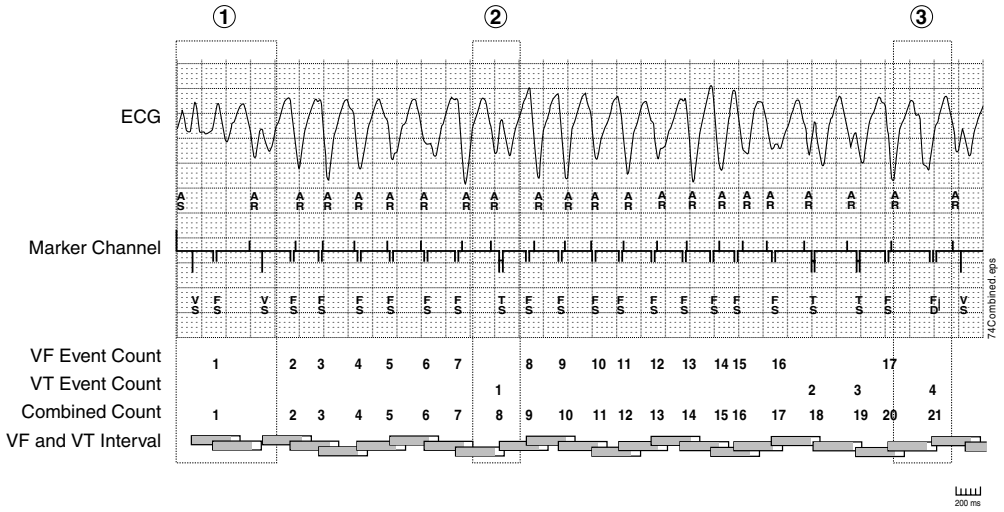
Table 6-2. CNID values for each initial or redetect VF NID value

VF NID	CNID	VF NID	CNID	VF NID	CNID
6/8	7	24/32	28	75/100	87
9/12	10	27/36	31	90/120	105
12/16	14	30/40	35	105/140	122
18/24	21	45/60	52	120/160	140
21/28	24	60/80	70		

Combined Count detection is fulfilled when the sum of the VF and VT event counts equals or exceeds the CNID. The device then reviews the last eight intervals and classifies the episode as

- VF, if any of the last eight were in the VF zone.
- FVT, if FVT Detection is enabled and none of the last eight was in the VF zone, but one or more was in the FVT zone.
- VT, if all eight were outside the VF zone (and FVT zone, if FVT detection is enabled).

Figure 6-8. Device detects VF with the Combined Count criterion



1 A slow VF episode starts, with a ventricular cycle length that varies between the VF and VT detection zones.

2 When a VT event occurs, the device increments the VT event count and the Combined Count.

3 The device detects VF even though the VF event count hasn't yet reached the VF Initial NID (18/24 in this example). The Combined Count reaches the CNID value of 21 first.

Monitoring episodes for termination or redetection

Once the device detects an arrhythmia, it considers the episode ongoing until it detects that the episode has ended. After delivering therapy, it monitors the ventricular rhythm using the programmed Redetect NIDs. If one of these NIDs is met, the device delivers the next programmed therapy for the detected arrhythmia.

See details about episode termination and redetection on page 85.

Parameters

* Medtronic nominal setting

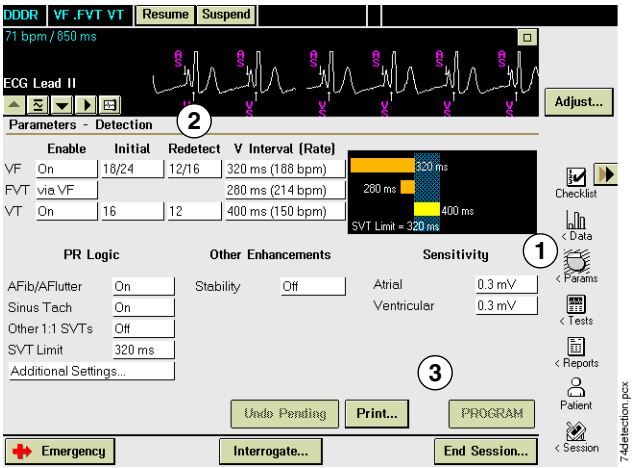
VF Redetect NID – Number of Intervals to Redetect: number of VF events the device must count to redetect a continuing VF after a therapy.	6/8, 9/12, 12/16*, 18/24, 21/28, 24/32, 27/36, 30/40
VT Redetect NID – Number of Intervals to Redetect: number of VT events the device must count to redetect a continuing VT after a therapy.	4, 8, 12*, . . . 52

Considerations

Review the following information before programming redetection parameters.

Initial and Redetect NIDs – You can expedite redetection by programming the VF and VT Redetect NIDs lower than the Initial NIDs.

How to program redetection parameters



1. Select Params > Detection.
2. Select the desired values for VT Redetect NID and VF Redetect NID.
3. Select [PROGRAM].

Details about episode termination and redetection

After a therapy is delivered, the device evaluates the ventricular rhythm to determine if the episode has terminated, is continuing, or has changed to a different arrhythmia.

Episode termination

The device determines that the episode has terminated if one of the following conditions occurs:

- eight consecutive ventricular intervals are greater than or equal to the programmed VT interval.[1]
- 20 seconds elapse with no ventricular intervals shorter than the programmed VT interval.[1]

After antitachycardia pacing therapy, the device begins evaluating intervals for episode termination on the first ventricular cycle. After cardioversion or defibrillation, the device begins evaluating intervals for episode termination on the second ventricular event. (Due to the extended post shock blanking, this event may be the *third* event on the electrogram.)

Note: Any subsequent detection after the end of the episode marks the start of a new episode.

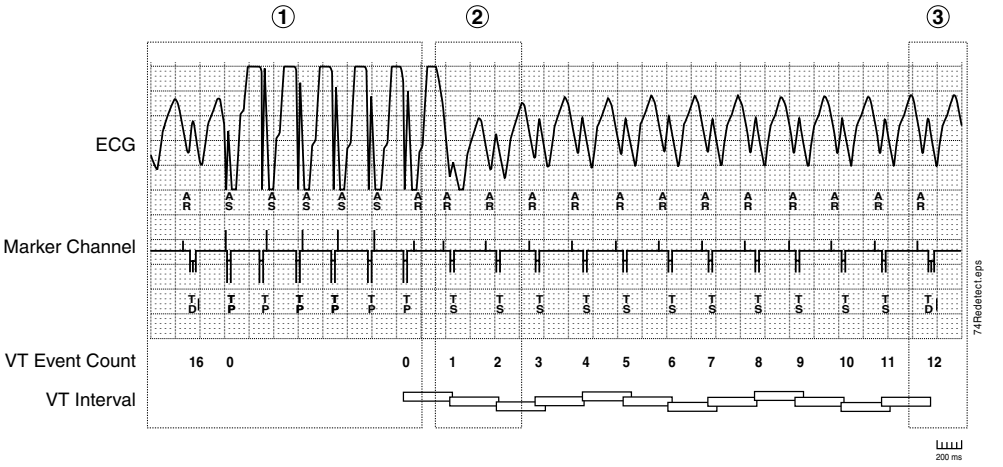
[1] VF interval if VT Detection is set to Off or Monitor, and the episode is a VF or an FVT via VF episode.

Episode redetection

After the device detects a tachyarrhythmia episode and delivers a therapy, the device redetects an arrhythmia if the VF or VT event count reaches the Redetect NID or if the combined VF and VT event count reaches the Redetect CNID (see “Detecting tachyarrhythmia episodes with Combined Count” on page 81).

The device then delivers the next programmed therapy for the current arrhythmia and resumes monitoring for the outcome of that therapy. Figure 6-9 shows an example of redetection.

Figure 6-9. VT episode redetected after therapy



1 A VT episode is detected, and the device delivers a Burst ATP therapy.

2 After therapy, the device continues to detect events in the VT zone.

3 When the VT event count reaches the VT Redetect NID, the device redetects the VT.

Notes:

- The device suspends VT detection (and Combined Count detection) for 17 events following a defibrillation therapy delivered in response to a detected VF.[1] Suspending VT detection helps avoid detecting transient VTs that can follow high voltage therapies.
- The PR Logic criteria are not applied during redetection. However, the Stability criterion may withhold detection or redetection of VT throughout an episode.

[1] If the defibrillation therapy is delivered as a result of a High Rate Timeout Therapy operation, VT detection is not suspended (see page 103).

VT acceleration

If the device redetects VT, it classifies the rhythm as accelerated if the average of the four intervals before redetection is at least 60 ms less than the average of the four intervals before initial VT detection. The most recent interval average is used to identify VT acceleration if VT is redetected again during the episode.

If the device redetects VF or an accelerated VT after an antitachycardia pacing sequence delivery, it skips the subsequent pacing therapy sequences for the duration of the episode and delivers the next therapy programmed for the current arrhythmia.

Enhancing detection with PR Logic criteria

The PR Logic detection criteria are designed to withhold inappropriate ventricular detection during episodes of rapidly conducted supraventricular tachycardia (SVT). The device analyzes the activation patterns and timing in both chambers using PR Logic pattern and rate analysis. This information helps identify evidence of atrial fibrillation, atrial flutter, sinus tachycardia, and other 1:1 SVTs. If this analysis indicates the presence of one or more of these rhythms, the device withholds detection.

For more information, see

- "Details about PR Logic pattern and rate analysis" on page 91
- "Details about the PR Logic detection criteria" on page 95

Parameters

* Medtronic nominal setting

AFib/AFlutter – Identifies rapidly conducted atrial fibrillation, atrial flutter, or atrial tachycardia.	On[a], Off*
Sinus Tach – Identifies sinus tachycardia.	On[a], Off*
1:1 VT-ST Boundary (%) **–** Threshold between the retrograde and antegrade zones used by A-V pattern analysis. Allows customizing of the Sinus Tach criterion for patients with slow one-to-one conduction.	35, 50*, 66, 75, 85
Other 1:1 SVTs – Identifies other one-to-one SVTs where the atrial and ventricular activation are roughly simultaneous.	On, Off*
SVT Limit (ms) **–** Defines the minimum ventricular interval at which the device applies the PR Logic criteria.	240, 250, . . ., 320*, 330, 340, . . ., 600

[a] When you set VT Detection Enable to On or Monitor, the AFib/AFlutter and Sinus Tach parameters are also automatically set to On.

Considerations

Review the following information before programming PR Logic parameters.

△ **Cautions:**

- Before enabling the Other 1:1 SVTs criterion, ensure that the atrial lead has matured. This criterion could inappropriately withhold therapy if atrial sensing is compromised by an unstable or dislodged atrial lead.
- Use caution when programming the Other 1:1 SVTs criterion in patients who exhibit slow 1:1 retrograde conduction during VF or VT. This criterion could inappropriately withhold VF/VT therapy in such patients. See “Pattern analysis of A-V and V-A intervals” on page 92.
- Use caution when programming the 1:1 VT-ST Boundary. Incorrect programming of this parameter can result in inappropriate therapies or underdetection of tachyarrhythmias.

PR Logic criteria and double tachycardia detection – When any of the PR Logic criteria are enabled, the device also enables double tachycardia detection (VF, VT, or FVT in the presence of an SVT; see page 100).

Sinus Tach and 1:1 VT-ST Boundary – When enabling the Sinus Tach criterion in patients who exhibit slow 1:1 retrograde conduction during VF or VT or slow antegrade conduction during SVTs, make sure to set the 1:1 VT-ST Boundary parameter appropriately. See “Customizing PR Logic for patients with slow conduction” on page 90.

VT Detection Enable, AFib/AFlutter and Sinus Tach – When you set VT Detection Enable to On or Monitor, the AFib/AFlutter and Sinus Tach parameters also automatically set to On.

SVT Limit – To ensure that therapy is delivered for hemodynamically compromising rates of any origin, the device always delivers therapy when the median ventricular interval is less than the programmed SVT Limit (nominally 320 ms) if VT, VF, or FVT detection criteria are satisfied.

VF Interval and SVT Limit – If you program an SVT Limit greater than the VF Interval, you are effectively disabling the PR Logic criteria for VF detection.

Customizing PR Logic for patients with slow conduction

Slow antegrade conduction during an SVT or slow 1:1 retrograde conduction during VT can adversely affect the accuracy of the Sinus Tach and Other 1:1 SVTs criteria. The 1:1 VT-ST Boundary parameter allows you to customize the Sinus Tach criterion for patients who exhibit slow conduction.

Note: Changing the 1:1 VT-ST Boundary parameter does not affect the operation of the Other 1:1 SVTs criterion. Use caution when enabling this criterion in patients who exhibit slow antegrade or retrograde conduction.

The 1:1 VT-ST Boundary parameter represents an A-V interval that is a percentage of a V-V interval. This value separates the retrograde and antegrade zones used by PR Logic pattern analysis operations. See “Pattern analysis of A-V and V-A intervals” on page 92.

If slow retrograde or antegrade conduction causes events to occur in the incorrect zone, you can use the 1:1 VT-ST Boundary parameter to increase the size of the appropriate zone. See Figure 6-10 on page 92.

If a patient exhibits slow antegrade or retrograde conduction and could benefit from a different 1:1 VT-ST Boundary setting, choose a new setting as follows:

- If the patient exhibits long V-A intervals during VT with 1:1 retrograde conduction, select 35%.
- If the patient exhibits long A-V intervals during an SVT, select a value that exceeds the A-V / V-V ratio observed during stored VT/VF or SVT episodes. See “EGM Strip” on page 285.

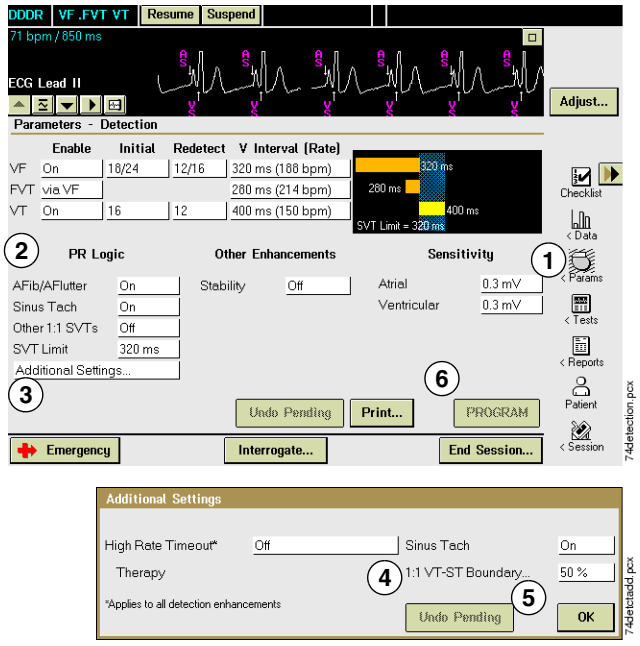
Restrictions

Review the following information before programming PR Logic parameters.

Sinus Tach and 1:1 VT-ST Boundary – The Sinus Tach criterion must be on before 1:1 VT-ST Boundary can be selected.

VT Detection Enable and SVT Limit – The SVT Limit must be shorter than the VT Interval (or VF Interval if VT Detection is off).

How to program the PR Logic detection criteria



1. Select Params > Detection.
2. Select the desired values for AFib/AFlutter, Sinus Tach, Other 1:1 SVTs, and SVT Limit.
3. If you need to adjust the 1:1 VT-ST Boundary for your patient, select Additional Settings....
4. Select the desired value for the 1:1 VT-ST Boundary.
5. Select [OK].
6. Select [PROGRAM].

Details about PR Logic pattern and rate analysis

PR Logic pattern and rate analysis is based on the following aspects of atrial and ventricular activation:

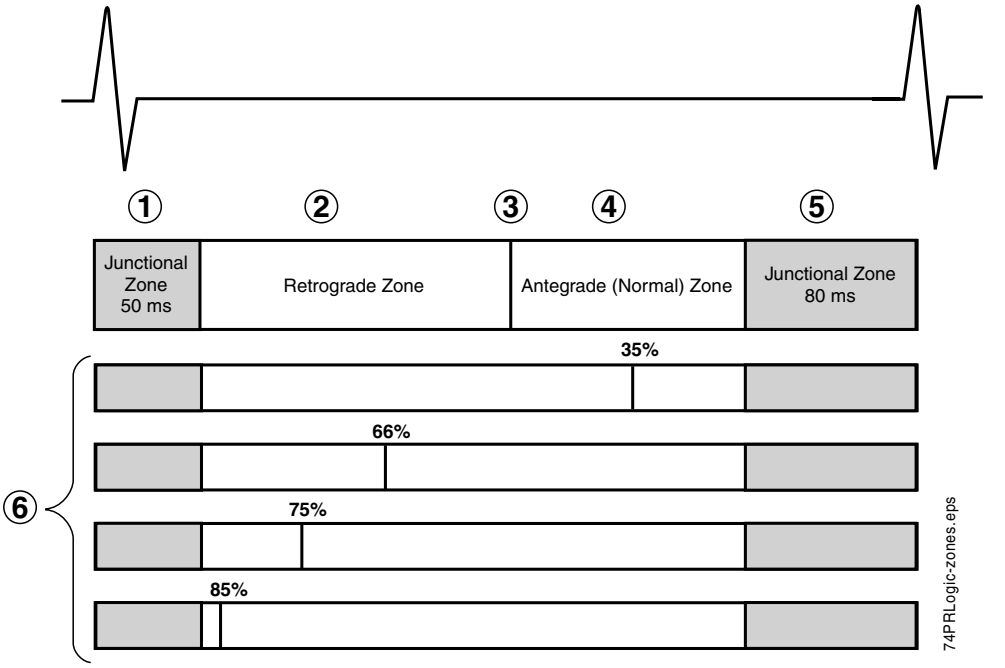
- A-V and V-A interval patterns
- atrial and ventricular rate
- AF evidence
- far-field R-wave sensing
- A:V dissociation
- V-V regularity

The information collected by PR Logic pattern and rate analysis is used by the PR Logic detection criteria to identify the presence of SVTs and withhold detection.

Pattern analysis of A-V and V-A intervals

The device uses pattern analysis to identify sinus tachycardia, atrial flutter, and other 1:1 SVTs. Within each V-V interval, the device categorizes the atrial rhythm according to the number of intervening atrial events and the zones in which those atrial events occur (see Figure 6-10). From this information, the device assigns pattern codes to the intervals, and interprets the pattern codes to identify SVTs.

Figure 6-10. Zones used during A-V pattern analysis



1 Atrial events in the first junctional zone indicate PAC, PVC, junctional rhythms, atrial fibrillation, or atrial flutter.

2 Atrial events in the retrograde zone indicate retrograde conduction of ventricular events.

3 The 1:1 VT-ST Boundary separates the retrograde and antegrade zones. The nominal value of this boundary is 50%.

4 Atrial events in the antegrade zone indicate normal conduction (sinus rhythm, sinus tachycardia).

5 Atrial events in the second junctional zone indicate PAC, PVC, junctional rhythms, atrial fibrillation, or atrial flutter.

6 The 1:1 VT-ST Boundary can be programmed to different values, changing the relative size of the antegrade and retrograde zones.

AF Evidence

AF Evidence is provided by a counter that accrues evidence to help identify atrial fibrillation or detect a double tachycardia (VF, VT, or FVT in the presence of an SVT; see page 100).

For each ventricular event, the device increments a running AF evidence count if it identifies all of the following conditions:

- A-V pattern information for a high atrial rate
- timing consistent with an atrial tachyarrhythmia (see Figure 6-10)
- greater than 1:1 conduction

If the A-V pattern is inconclusive, inconsistent, or if the device detects far-field R-wave sensing, the AF Evidence count is unchanged. If no atrial event occurs within the current V-V interval or a consistent 1:1 pattern is present, the device subtracts one from the count.

The AF Evidence criterion is satisfied when the AF Evidence count is greater than or equal to six. Once the criterion is met, it remains satisfied for as long as the AF Evidence count is greater than or equal to five.

Far-field R-wave sensing

The device identifies far-field R-wave oversensing in the atrium in order to exclude far-field R-waves from SVT classification.

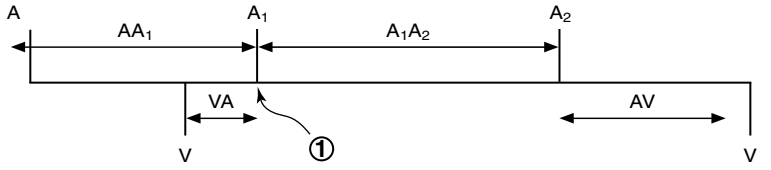
If there are two atrial events within a ventricular interval, one atrial event may actually be a far-field R-wave (see Figure 6-11). The device identifies a sensed far-field R-wave if it detects both of the following conditions:

- a short-long pattern of A-A intervals
- a short A-V interval (< 60 ms) or a short V-A interval (< 160 ms)

The device uses far-field R-wave sensing for the Sinus Tach and AFib/AFlutter criteria as follows:

- To identify sinus tachycardia with far-field R-wave sensing, the device requires a far-field R-wave on at least four of the most recent 12 ventricular intervals.
- To identify atrial fibrillation or atrial flutter with far-field R-wave sensing, the device requires a far-field R-wave on at least 10 of the most recent 12 ventricular intervals.

Figure 6-11. Intervals measured for far-field R-wave detection



1 Far-field R-wave.

A:V Dissociation

A:V Dissociation provides cumulative evidence that there is no direct relationship between sensed atrial and ventricular events. The device identifies a rhythm as A:V dissociated if at least four of the most recent eight ventricular intervals exhibit either

- no atrial events in the ventricular interval
- an A-V interval that differs from the average of the previous eight A-V intervals by more than 40 ms

The device uses this count to help identify a double tachycardia (VF, VT, or FVT in the presence of an SVT).

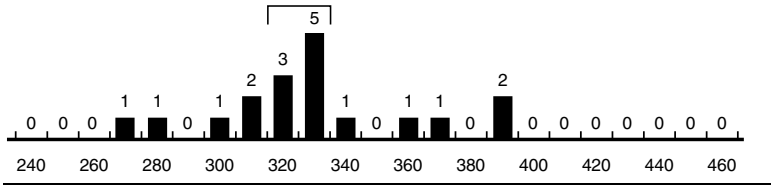
Ventricular cycle length regularity

The device uses ventricular cycle length regularity or irregularity to evaluate atrial fibrillation, double tachycardia (VF, VT, or FVT in the presence of an SVT), and other 1:1 SVTs.

The device continuously measures the regularity of the ventricular intervals. The regularity count indicates how often the two most commonly occurring intervals (of at least 240 ms) occurred among the last 18 ventricular intervals.

For example, Figure 6-12 illustrates the 18 most recent intervals. The two most frequently occurring intervals are 330 ms (five intervals) and 320 ms (three intervals). Together these account for eight of the 18 most recent intervals, for a regularity count of 44%.

Figure 6-12. Regularity of ventricular cycle length



- For a double tachycardia to be detected, the regularity count must be at least 75%.
- To withhold detection under the atrial fibrillation rule of the AFib/AFlutter criterion, the regularity count must be 50% or less. Atrial fibrillation that exhibits greater regularity (between 50% and 75%) may be identified by the atrial flutter rule, which does not require the regularity count.
- To withhold detection for Other 1:1 SVTs, the regularity count must be at least 25%.

Details about the PR Logic detection criteria

The PR Logic detection criteria are applied to initial detection of VT, FVT, or VF. They are not applied during redetection. The device withholds episode detection if all of the following conditions occur:

- An initial NID is met (VT, VF, or Combined).
- One or more of the PR Logic detection criteria is met.
- The V-V median interval equals or exceeds the SVT Limit.

AFib/AFlutter criterion

The AFib/AFlutter criterion consists of two independent rules: the atrial fibrillation rule and the atrial flutter rule. If either rule is satisfied, the AFib/AFlutter criterion is met, and the device withholds ventricular detection and therapy.

The atrial fibrillation rule requires that all the following conditions occur:

- The AF Evidence counter indicates atrial fibrillation, without far-field R-wave sensing.
- The A-A median interval is 94% or less of the V-V median interval.
- The ventricular cycle length is not regular (regularity of 50% or less).

The atrial flutter rule is satisfied if A-V pattern information indicates atrial flutter, without far-field R-wave sensing.

Sinus Tach criterion

The Sinus Tach criterion is met if A-V pattern analysis indicates a 1:1 sinus tachycardia without far-field R-wave sensing (with atrial events primarily in the antegrade zone shown; see Figure 6-10 on page 92).

The size and timing of the antegrade zone is dependent on the 1:1 VT-ST Boundary parameter. See “Customizing PR Logic for patients with slow conduction” on page 90.

The Sinus Tach criterion also recognizes and withholds inappropriate detection for a 1:1 sinus tachycardia when far-field R-wave oversensing occurs consistently.

Other 1:1 SVTs criterion

The Other 1:1 SVTs criterion is satisfied when A-V pattern information indicates a 1:1 SVT in which the atria and ventricles are activated at approximately the same time, as in a junctional tachycardia (consistent atrial sensing in a junctional zone). See Figure 6-10 on page 92.

Enhancing VT detection with the Stability criterion

Stability is designed to prevent detection of unstable ventricular rhythms such as VT because rapidly conducted atrial fibrillation episodes often cause irregular ventricular rhythms. The device resets the VT count if a ventricular interval is unstable.

See details about the Stability criterion on page 98.

Parameters

* Medtronic nominal setting

Stability (ms) – interval threshold used to identify unstable ventricular intervals	Off*, 30, 40, . . ., 100

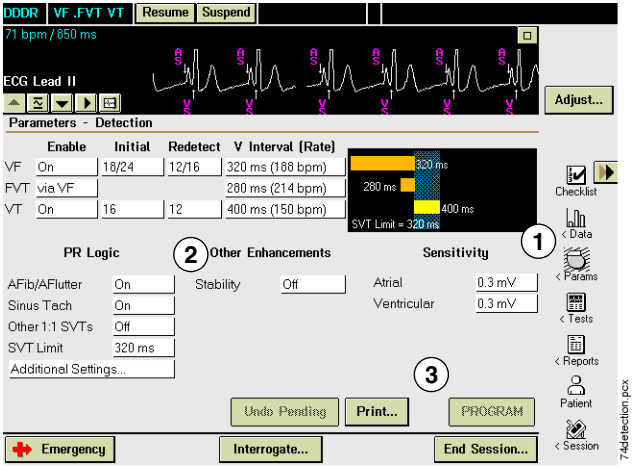
Considerations

Review the following information before programming Stability parameters.

Stability interval – A small Stability value may not allow for normal VT interval variation and may decrease the sensitivity of the device to detect VT.

Stability and interval rounding – The Stability criterion compares intervals that have been shortened to multiples of 10 ms, permitting a rounding difference of up to +10 ms from the programmed Stability value.

How to program Stability



To program Stability:

1. Select Params > Detection.
2. Select the desired value for Stability.
3. Select [PROGRAM].

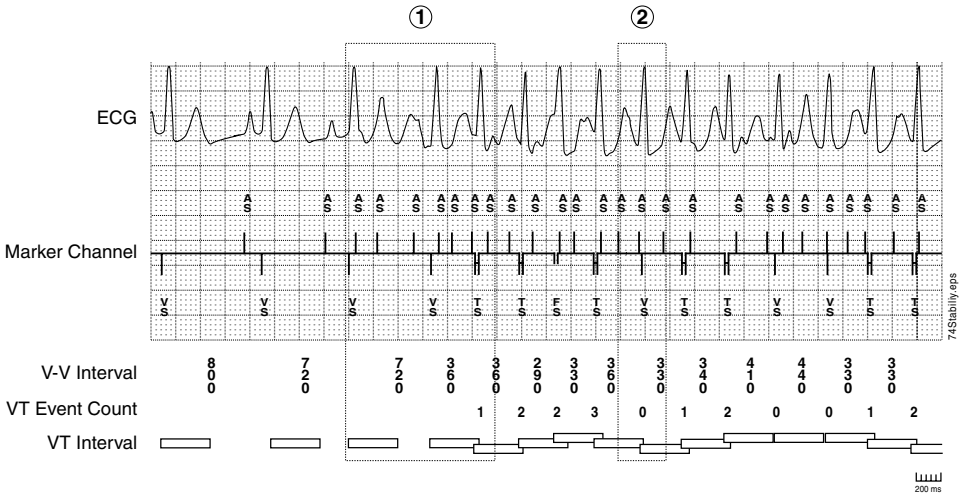
Details about Stability

The Stability criterion checks all ventricular intervals in the VT or FVT via VT detection zones for stability. An interval is unstable if the difference between it and any of the three previous intervals is greater than the programmed Stability interval.

The device does not apply the Stability option until the VT event count reaches at least three. If the device classifies an event as unstable, it is marked as a normal sensed event, and the VT event count resets to zero (see Figure 6-13).

Note: Stability applies throughout initial detection and redetection of VT and FVT via VT.

Figure 6-13. Stability resets the VT event count during atrial fibrillation



1 Atrial fibrillation starts, which is conducted into the ventricle at a rapid rate.

2 After the VT event count reaches 3, the device applies the Stability criterion. Because the 360 ms interval differs from the 290 ms interval by more than the programmed Stability interval (50 ms, in this case), the Stability criterion resets the VT event count.

Detecting double tachycardias

To ensure proper detection and therapy during double tachycardia episodes (VT, FVT, or VF in the presence of SVT), the device provides double tachycardia detection whenever PR Logic detection criteria are enabled. The device detects double tachycardia episodes using both rate and PR Logic pattern and rate analysis information.

Details about double tachycardia detection

If PR Logic pattern and rate analysis identifies a double tachycardia, the device delivers the programmed therapies for the ventricular arrhythmia.

The device detects VF or FVT via VF in the presence of SVT if all of the following occur:

- The AF Evidence counter indicates atrial fibrillation, exclusive of far-field R-wave sensing.
- Ventricular detection occurs via the Interval or Combined Count criterion.
- The V-V median interval is greater than or equal to the SVT Limit.
- The rhythm is A:V dissociated.

The device detects VT or FVT via VT in the presence of SVT if these criteria are met and

- the ventricular cycle length is very regular (regularity of at least 75%).

Detecting prolonged tachyarrhythmias with High Rate Timeout

To ensure that fast ventricular rates are treated, the device provides High Rate Timeout. If a fast rhythm occurs, and the device withholds detection due to the PR Logic or Stability criteria, High Rate Timeout waits a programmable length of time and then suspends these criteria until the episode terminates. High Rate Timeout also includes the option to skip directly to VF therapies during sustained high rate episodes.

See details about High Rate Timeout on page 102.

Parameters

* Medtronic nominal setting

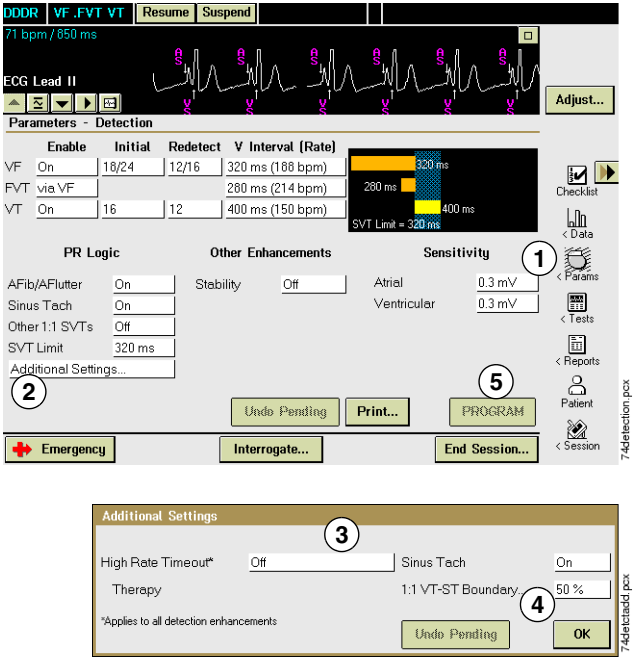
High Rate Timeout (min) – Disables supplementary SVT detection criteria when high rate episode continues longer than the programmed time limit.	Off*, 0.75, 1, 1.25, 1.5, 2, 2.5, . . ., 5, 6, 7, . . ., 20, 22, 24, . . ., 30
High Rate Timeout Therapy – Option to treat sustained high rate episodes with the therapies for the detected episode type or to treat all high rate timeout episodes with VF defibrillation therapy (with no VF confirmation).	Zone Appropriate*, Skip to VF Therapy

Considerations

Review the following information before programming High Rate Timeout parameters.

High Rate Timeout and inappropriate therapies – Because High Rate Timeout can disable the PR Logic and Stability detection criteria, it may cause the device to deliver tachyarrhythmia therapies inappropriately (for example, during sinus tachycardia or atrial fibrillation).

How to program High Rate Timeout



To program High Rate Timeout:

1. Select Params > Detection.
2. Select Additional Settings... .
3. Select the desired values for High Rate Timeout and Therapy.
4. Select [OK].
5. Select [PROGRAM].

Details about High Rate Timeout

High Rate Timeout starts a timer when VF, FVT, or VT would have been detected but was not because of the operation of the Stability or PR Logic detection criteria.

Note: A monitored VT episode cannot start the High Rate Timeout timer.

Once the timer has started, it continues until one of the following conditions occurs:

- The timer meets the programmed duration.
- A VF, FVT, or VT episode is detected while the SVT detection criteria are enabled.
- The device determines that the high rate has ended (using the episode termination criteria; see page 85).

If the high rate timer reaches the programmed duration, the ICD disables all SVT detection criteria. These criteria remain disabled until one of the following conditions occurs:

- A VF, FVT, or VT episode is detected and terminates.
- The device determines that the high rate has ended (using the episode termination criteria; see page 85).

High Rate Timeout Therapy

If the High Rate Timeout Therapy parameter is set to Skip to VF Therapy, the device delivers only VF defibrillation therapies (with VF Confirmation disabled) for sustained high rate episodes, whether detected as VT, FVT, or VF. If set to Zone Appropriate, the device delivers the VT, FVT, or VF therapy for the detected rhythm, and VF Confirmation remains active for the first VF therapy if it is enabled.

Note: The device does not suspend VT detection for 17 events following a defibrillation therapy that is delivered as a result of the High Rate Timeout “Skip to VF Therapy” operation.

Key terms

1:1 VT-ST Boundary – programmable percentage of a V-V interval that indicates the division between the Retrograde and Antegrade zones used by PR Logic pattern and rate analysis operations.

auto-adjusting sensitivity – after each sensed or paced event, the sensitivity thresholds briefly assume less sensitive settings to prevent sensing of T-waves and pacing artifacts.

blanking period – time interval after each pacing pulse, sensed event, or shock, when no sensing can occur.

CNID (combined number of intervals to detect) – number of events counted on both the VT and VF event counters required for Combined Count detection. The device calculates the CNID by multiplying the VF NID by 7/6 and rounding down.

detection – condition occurring when the device identifies the presence of a tachyarrhythmia episode.

double tachycardia – VF, VT, or FVT in the presence of an SVT. Double tachycardia detection ensures that the PR Logic criteria do not compromise ventricular detection in the presence of a double tachycardia.

electromagnetic interference (EMI) – radiated or conducted energy, either electrical or magnetic, that can interfere with the device sensing operation in some circumstances.

episode – period of time between tachyarrhythmia detection and termination.

event – a sensed or paced beat.

FVT detection via VF – condition occurring when the device identifies the presence of a fast ventricular tachycardia using the VF event counter and an FVT Interval less than the VF interval.

FVT detection via VT – condition occurring when the device identifies the presence of a fast ventricular tachycardia using the VT event counter and an FVT Interval greater than the VF interval.

FVT episode – period of time between FVT detection and termination.

FVT event – a sensed beat that falls within the FVT detection zone between the programmed FVT Interval and VF Interval.

FVT Interval – (also called FTI) programmable interval used to define the FVT detection zone. FVT via VF detection requires that the FVT Interval be shorter than the VF Interval. FVT via VT detection requires that the FVT Interval be longer than the VF Interval, but not greater than the VT Interval.

FVT plus SVT – see “double tachycardia”.

High Rate Timeout – feature that ensures fast ventricular rates are treated by limiting the time that SVT Detection criteria (Stability or PR Logic) can withhold detection. Episodes detected after the High Rate Timeout timer expires can be treated with zone appropriate therapies or with VF therapies (with VF confirmation disabled).

median interval – (atrial or ventricular) the seventh in a numerically ordered list of the 12 most recent A-A or V-V intervals.

NID (number of intervals to detect) – number of arrhythmic intervals required for the device to detect or redetect a tachyarrhythmia.

Pace Blanking – parameter that disables sensing for a programmable number of milliseconds after each pacing output to avoid inappropriate sensing of artifacts or T-waves.

PR Logic criteria – (AFib/AFlutter, Sinus Tach, and Other 1:1 SVTs) optional detection criteria that analyze both atrial and ventricular rhythms to discriminate between ventricular and supraventricular arrhythmias.

redetection – condition occurring when the device identifies the continued presence of a tachyarrhythmia after therapy. During redetection the device applies the VF Redetect NID and VT Redetect NID.

refractory period – time interval during which the device senses events, but marks them as refractory, and responds to them in a limited way. Refractory periods affect bradycardia pacing and synchronization of high voltage therapies, but not tachyarrhythmia detection.

sensed event – electrical activity across the sensing electrodes that exceeds the programmed sensitivity threshold.

sensitivity – degree to which the sensing circuitry is responsive to intracardiac signals.

Stability criterion – programmable VT detection criterion that allows the device to screen out irregular ventricular rhythms or unstable VTs (for example, those caused by the conduction of atrial fibrillation or flutter).

termination – condition occurring when the device determines that an episode has ended. The device detects episode termination when either eight consecutive V-V intervals occur or 20 seconds elapse with no V-V intervals shorter than any of the programmed detection intervals.

VF detection – condition occurring when the device identifies the presence of ventricular fibrillation.

VF episode – period of time between VF detection and termination.

VF event – a sensed beat that is shorter than the programmed VF Interval.

VF Interval – (also called FDI) programmable interval used to define the VF detection zone. V-V intervals shorter than the VF Interval are counted as VF events.

VF NID (number of intervals to detect) – (also called VF Initial NID) number of VF events required for initial VF detection to occur.

VF plus SVT – see “double tachycardia”.

VF Redetect NID (number of intervals to redetect) – number of VF events required for a VF episode to be redetected after therapy.

VT acceleration – redetection in the VT zone with an average cycle length at least 60 ms shorter than at initial detection.

VT detection – condition in which the device identifies the presence of ventricular tachycardia.

VT episode – period of time between VT detection and termination.

VT event – a sensed beat that falls within the VT detection zone. That is, an interval that is shorter than the programmed VT Interval, but greater than or equal to the programmed VF Interval and/or FVT Interval.

VT Interval – (also called TDI) programmable interval used to define the VT detection zone. V-V intervals shorter than the VT Interval but greater than or equal to the VF and/or FVT Interval are counted as VT events.

VT monitoring – A programmable option that allows the device to detect fast rhythms as VT and record episode data without delivering VT therapy.

VT NID (number of intervals to detect VT) – (also called VT Initial NID) programmable number of consecutive VT events required for initial VT detection to occur.

VT plus SVT – see “double tachycardia”.

VT Redetect NID (number of intervals to redetect VT) – number of consecutive VT events required for a VT episode to be redetected after therapy.

zone merging – feature that merges an FVT detection zone with its parent detection zone after detection (for example, a FVT via VF detection zone merges into the VF zone). The merged zone uses the event counting and therapies designated for the faster arrhythmia.

Treating tachyarrhythmia episodes

7

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Treating VF with defibrillation

The device can respond to a VF episode by delivering defibrillation therapy to the patient's heart. The defibrillation therapy is intended to terminate the VF episode by simultaneously depolarizing the heart tissue and restoring the patient's normal sinus rhythm.

You can program the device to deliver a sequence of up to six defibrillation therapies, each with specific energy and pathway settings. If the first therapy is unsuccessful and the device redetects VF, it delivers the next programmed defibrillation therapy.

See details about VF therapy on page 112.

Parameters

* Medtronic nominal setting

VF Therapy Status – Turns a specific VF Therapy on or off.	On*, Off
Energy (J) – Amount of energy delivered to the heart by the therapy.	0.4, 0.6, . . ., 1.8, 2, 3, . . ., 16, 18, 20, . . ., 30*
Pathway – Direction the electrical current flows through the heart.	AX>B*, B<AX
Confirm VF after initial detection? – Option that requires the device to confirm the presence of the VF rhythm during and after charging before delivering the first programmed VF therapy.	Yes*, No
Active Can – Option to select the device can as an active electrode for delivering defibrillation and cardioversion therapies.	On*, Off

Notes:

- VF Therapy Status, Energy, and Pathway are programmed separately for each VF therapy.
- For VF therapies 3 - 6, energy settings below 10 J are not available.

Considerations

Review the following information before programming VF Therapy parameters.

△ **Caution:** If the Active Can feature is turned off, the device delivers defibrillation and cardioversion therapies between the RV (HVB) and SVC (HVX) electrodes only. To ensure the device can deliver defibrillation and cardioversion therapies, make sure a supplementary HVX electrode is implanted and connected to the device before turning Active Can off.

Active Can – The programmed setting for Active Can applies to the following high voltage operations:

- automatic, manual, and emergency cardioversion
- automatic, manual, and emergency defibrillation
- T-shock inductions.

Energy – Programming the first VF therapy to an optimized value (for example, the defibrillation threshold plus 10 J) can expedite delivery and help extend battery longevity. All other VF therapies should be programmed to 30 J.

Confirm VF after initial detection – When Confirm VF after initial detection is set to Yes, the device verifies that a VF episode is in progress before delivering the first programmed defibrillation therapy. However, subsequent therapies for that episode, and re-applications of an aborted first therapy, are always delivered without confirmation.

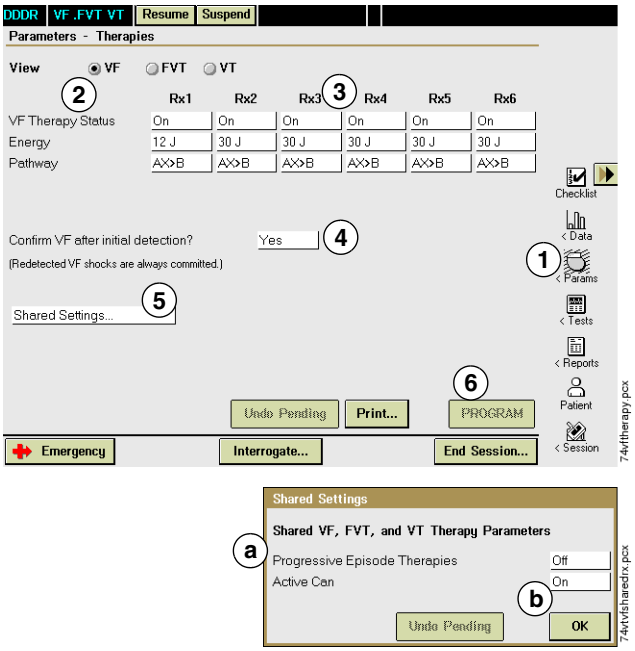
Progressive Episode Therapies – If Progressive Episode Therapies is turned on, the device may deliver a high voltage therapy at a higher energy level than is programmed. This ensures that each therapy delivered during an ongoing episode is at least as aggressive as the previous therapy (see page 139).

Restrictions

Review the following information before programming VF Therapy parameters.

Energy – The energy settings for VF therapies 3 - 6 must be programmed to 10 J or greater. In addition, VF therapies must be programmed to be at least equal to the energy of the previous therapy or increasingly aggressive. That is, one VF therapy cannot be followed by another with a lower energy setting.

How to program VF therapies



To program VF therapies:

1. Select Params > Therapies.
2. Select [VF].
3. For each therapy (Rx1 - Rx6), select the desired values for VF Therapy Status, Energy, and Pathway.
4. Select a value for “Confirm VF after initial detection?”
5. To change the Active Can parameter value, select Shared Settings... .
   a. Select a value for Active Can.
   b. Select [OK].
6. Select [PROGRAM].

Details about VF therapy

The device provides up to six defibrillation therapies to treat VF episodes. If a VF episode is detected, the device begins charging its high voltage capacitors. Once the capacitors are charged to the programmed energy, the device attempts to deliver the defibrillation pulse simultaneously with a sensed ventricular event. If the therapy cannot be synchronized to a sensed ventricular event, the device delivers the therapy asynchronously.

If the device is set to confirm VF after initial detection, the device attempts to confirm the continued presence of the VF episode during and after charging for the first programmed therapy. If the rhythm stops, the device cancels the therapy. Otherwise, the device delivers the defibrillation therapy synchronized to a ventricular event.

Capacitor charging period

To deliver a defibrillation therapy, the device must first charge its high voltage capacitors to the programmed energy. The length of time required to charge the capacitors depends on the programmed energy, battery depletion, and the time since the last capacitor formation. Table 1-6 on page 10 shows typical full energy capacitor charging periods.

Delivery pathway electrodes

The device can deliver defibrillation therapies via the following high voltage electrodes:

- Can (HVA) – device can
- RV (HVB) – RV coil
- SVC (HVX) – optional electrode (for example, an SVC coil)

If an optional electrode is used, you can disable the Active Can feature. If you do so, the device delivers defibrillation therapies between the RV (HVB) and SVC (HVX) electrodes only.

Energy

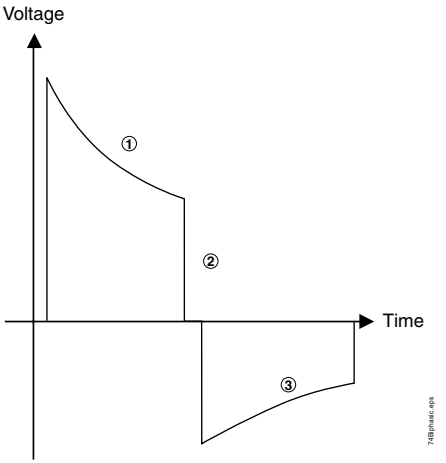
The device can deliver up to 30 joules,[1] which corresponds to a stored energy of 35 joules.[2] For a comparison of delivered and stored energy levels, see Table 1-7 on page 11. The defibrillation energy level is programmed independently for each VF therapy.

[1] Delivered energy of biphasic waveform into 75 ohms.
[2] Derived from the peak capacitor voltage, which is always greater than the energy delivered by the device.

Waveform

The device delivers defibrillation therapies using a biphasic waveform, which consists of two phases. In the first phase, current is delivered until the pulse decays to 50% of its original voltage. The device then truncates the phase and reverses the current pathway for the second phase.When the second phase of the pulse decays to 50% of its original voltage, the device truncates the pulse.

Figure 7-1. Defibrillation pulse waveform



1 The first segment of the pulse decays to 50% of the original voltage.
2 The pulse is truncated and the polarity is reversed.
3 The second segment of the pulse decays to 50% and then is truncated.

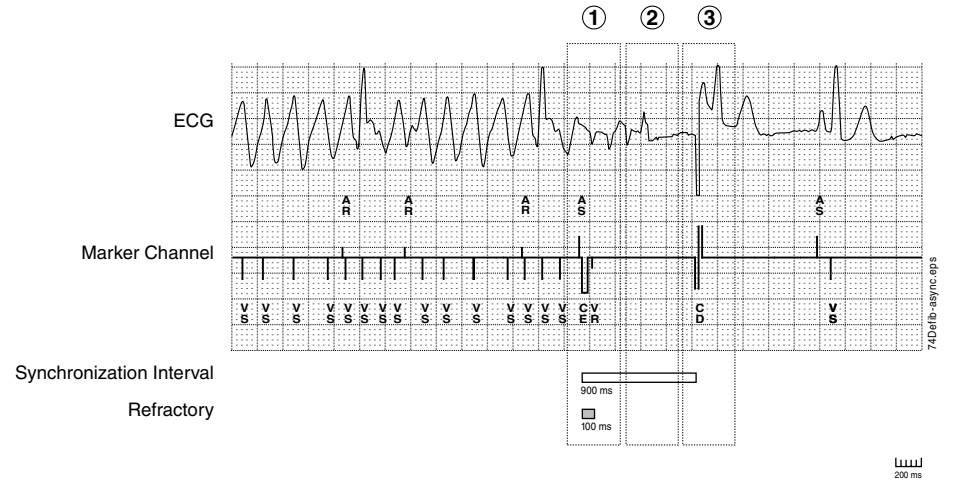
Synchronizing defibrillation without confirming VF

If the device is not set to confirm VF after initial detection or has already delivered the first VF therapy for an episode, the device attempts to synchronize the defibrillation therapy to a ventricular event, but delivers the therapy asynchronously if necessary.

Once the capacitors are charged to the programmed energy, the device starts the synchronization process with a 900 ms delivery timer. If a qualified ventricular sensed event occurs during this period, the device delivers the defibrillation therapy synchronized to the event. Otherwise, the device delivers the therapy asynchronously when the timer expires (see Figure 7-2).

Any sensed ventricular event qualifies for therapy delivery unless it is a refractory event or an AVP event. If a refractory event occurs, the device ignores it and continues to attempt to synchronize. If an AVP event occurs, the device resets the delivery timer to 500 ms and continues to attempt to synchronize.

Figure 7-2. Defibrillation delivered asynchronously



1 After detecting VF, the device completes charging and starts a 100 ms refractory period and a 900 ms synchronization interval. The device does not deliver the charge synchronized to the refractory event.

2 Several low-amplitude VF events go unsensed.

3 After 900 ms pass, the device delivers the defibrillation therapy asynchronously.

Confirming VF after initial detection

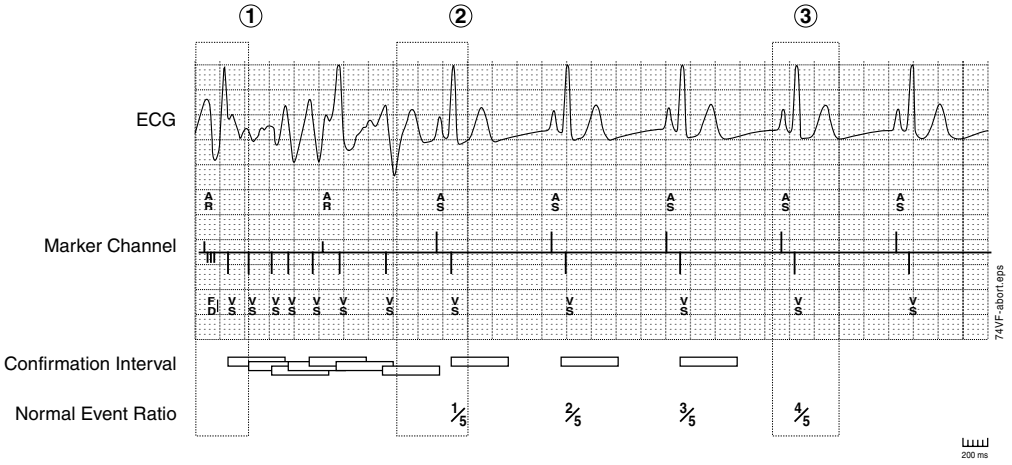
If the device is set to confirm VF after initial detection, and the device begins charging its capacitors for the first VF therapy, the device monitors the cardiac rhythm during and after charging to confirm that the VF remains present before delivering the therapy.

The device confirms the continued presence of VF using a sequence of confirmation intervals, each lasting 60 ms plus the programmed VT Interval.[1] It classifies any ventricular event that occurs within the confirmation interval as “arrhythmic” and any events after the interval as “normal.”

[1] Or VF Interval, if VT Detection is set to Off or Monitor.

On each ventricular event, the device reviews the last five events since charging started. If four of the last five ventricular events were normal, the device stops charging and cancels the therapy (see Figure 7-3).

Figure 7-3. Defibrillation therapy cancelled during charging when VF terminates spontaneously



1 The device detects VF and begins confirmation, using a confirmation interval of 460 ms (VT Interval + 60 ms).

2 The VF spontaneously terminates, and normal sinus rhythm resumes.

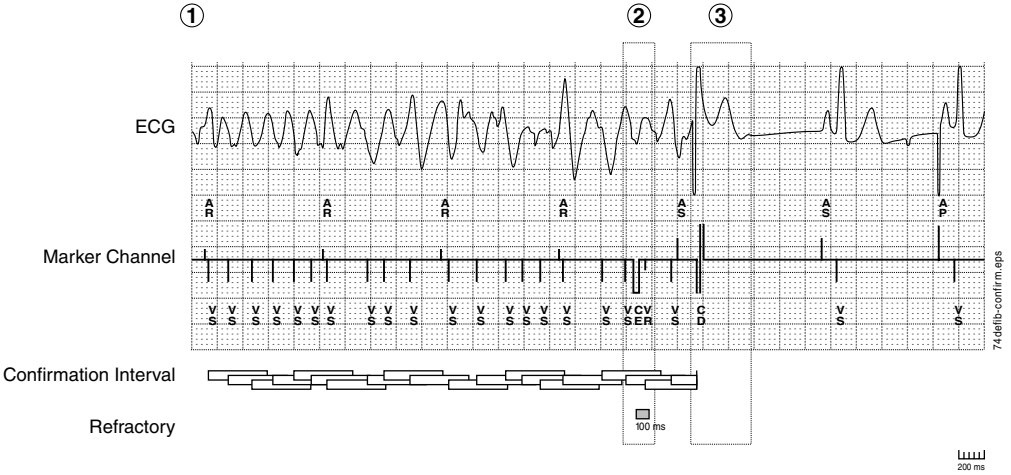
3 Once four of five events occur that are greater than the confirmation interval, the device cancels the therapy and stops charging.

Once charging ends, the device attempts to synchronize the defibrillation therapy to a qualified ventricular event but also continues to confirm the presence of VF. An event qualifies for delivery if it is non-refractory and qualifies as one of the following events:

- the second arrhythmic ventricular event and is outside an AVP interval
- the third arrhythmic ventricular event

The device continues to attempt to synchronize until it delivers the defibrillation therapy (see Figure 7-4) or it fails to confirm the presence of VF and cancels the therapy.

Figure 7-4. VF confirmed and defibrillation synchronized to an arrhythmic event



1 The device has detected VF, is charging its capacitors for defibrillation, and is confirming VF using a confirmation interval of 460 ms (VT Interval + 60 ms).

2 The device completes charging and starts a 100 ms refractory period while continuing VF confirmation. A refractory event occurs, and the device starts a new confirmation interval.

3 On the second arrhythmic event after charging, the device delivers the defibrillation therapy.

Refractory events

During the synchronization process, the device classifies events as refractory if they occur during any of the following refractory periods:

- 400 ms after charging starts
- 400 ms after a ventricular or atrial paced event
- 100 ms after charging ends

AVP events

The device postpones a defibrillation scheduled to be delivered during an Atrial Vulnerable Period (AVP) until the next qualifying event. The AVP is a 250 ms interval, starting 150 ms after a sensed atrial event, during which a high voltage pulse might induce an atrial tachyarrhythmia. AVP operation can only postpone the therapy for one event during synchronization.

Bradycardia pacing during defibrillation

On the first ventricular event after charging, the device changes the pacing mode to VVI and sets the pacing interval as shown in Table 7-1.

Table 7-1. Pacing interval used during defibrillation

VF confirmation	Programmed Pacing mode	Pacing interval
Active	ODO	2000 ms (30 ppm)
Active	DDD, DDI, VVI, AAI, DDDR, DDIR, VVIR, or AAIR	Pacing interval used before charging started
Inactive	Any	1200 ms (50 ppm)

After delivering the defibrillation therapy

Immediately after delivering a defibrillation therapy, the device starts both of these operations:

- a post shock blanking period of 520 ms in each chamber
- a VVI pacing cycle at 50 ppm (1200 ms pacing interval)

After the first ventricular event, the programmed bradycardia pacing mode resumes using the Post Shock pacing parameters. See “Providing pacing after high voltage therapies” on page 196.

The device monitors for either the end of the episode or redetection.

The device suspends VT detection (and Combined Count detection; see page 81) for 17 events following a defibrillation therapy delivered in response to a detected VF. Suspending VT detection helps avoid detecting transient VTs that can follow high voltage therapies.[1]

After a cancelled defibrillation therapy

If the device cancels a defibrillation therapy, it reverts immediately to the programmed bradycardia pacing settings (not the Post-Shock pacing parameters).

The device resumes monitoring for arrhythmias after the next paced or sensed ventricular event. If the device detects the same arrhythmia again, it attempts to synchronize and deliver the same therapy. However, if the episode ends, it resumes normal detection.

Note: If the device cancels the defibrillation therapy leaving energy stored on the capacitors, the delivered energy of the next high voltage therapy may be higher than the programmed value.

[1] If the defibrillation therapy is delivered as a result of a High Rate Timeout therapy operation, VT detection is not suspended (see page 103).

Treating VT and FVT with antitachycardia pacing

The device can respond to a VT or FVT episode by delivering antitachycardia pacing (ATP) or cardioversion therapy to the patient's heart. ATP therapies are designed to interrupt the reentrant activation pattern of a VT or FVT with pacing stimuli, restoring the patient's normal sinus rhythm. Because ATP therapies use pacing-level stimulation instead of high voltage shocks, they are much less painful for the patient than cardioversion therapy.

You can program the device to deliver a sequence of up to six VT therapies and six FVT therapies and can program a portion of these as ATP therapies. You can select Burst, Ramp, or Ramp+ ATP therapy and can set the parameters for each enabled therapy separately.

See details about ATP therapies on page 124.

Parameters for all ATP therapies

* Medtronic nominal setting

VT (or FVT) Therapy Status – Enables or disables a VT Therapy or FVT Therapy.	On*, Off
Therapy Type – Cardioversion or ATP therapy to treat VT or FVT episodes (choose Burst, Ramp, or Ramp+ to enable ATP therapy).	CV, Burst, Ramp, Ramp+
Anti-Tachy Pacing Minimum Interval (ms) – Minimum pacing interval for all ATP therapies.	150, 160, . . ., 200*, . . ., 400
V. Amplitude (V) – Voltage of the ventricular pacing pulses delivered during all ATP pacing pulses.	0.5, 1, . . ., 4, 5, 6, 8*
V. Pulse Width (ms) – Duration of the ventricular pacing pulses delivered during all ATP therapies.	0.03, 0.06, 0.1, 0.2, . . ., 1.6*
V. Pace Blanking (ms) – Ventricular blanking period following the pacing pulses delivered during all ATP therapies.	150, 160, . . ., 240*, . . ., 440

Parameters for Burst therapy

* Medtronic nominal setting

	VT therapies	FVT therapies
Initial # Pulses – Number of pulses in all Burst therapy sequences.	1, 2, . . ., 6*, . . ., 15	1, 2, . . ., 8*, . . ., 15
R-S1 Interval (%) – Pacing interval of the first Burst therapy sequence as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66, . . ., 84*, 88, 91, 94, 97	50, 53, 56, 59, 63, 66, . . ., 84, 88*, 91, 94, 97
Interval Decrement (ms) – Pacing interval decrement per sequence for the remaining Burst sequences.	0, 10*, . . ., 40	0, 10*, . . ., 40
# Sequences – Number of sequences in the Burst therapy.	1, 2, 3*, . . ., 10	1*, 2, 3, . . ., 10

Parameters for Ramp therapy

* Medtronic nominal setting

Initial # Pulses – Number of pulses in first Ramp sequence.	1, 2, . . ., 8*, . . ., 15
R-S1 Interval (%) – Pacing interval of the first Ramp pulse as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66, . . ., 84, 88, 91*, 94, 97
Interval Decrement (ms) – Pacing interval decrement per pulse during a Ramp sequence.	0, 10*, . . ., 40
# Sequences – Number of sequences in the Ramp therapy.	1, 2, 3*, . . ., 10

Parameters for Ramp+ therapy

* Medtronic nominal setting

Initial # Pulses – Number of pulses in first Ramp+ sequence.	1, 2, 3*, . . ., 15
R-S1 Interval (%) – Pacing interval of the first Ramp+ pulse as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66, . . ., 75*, . . ., 84, 88, 91, 94, 97
S1-S2 Interval (%) – Pacing interval of the second Ramp+ pulse as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66, 69*, . . ., 84, 88, 91, 94, 97
S2-SN Interval (%) – Pacing interval of the remaining Ramp+ pulses as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66*, . . ., 84, 88, 91, 94, 97
# Sequences – Number of sequences in the Ramp+ therapy.	1, 2, . . ., 5*, . . ., 10

Considerations

Review the following information before programming ATP therapy parameters.

VT and FVT therapies – You should not use ATP therapies exclusively to treat VT or FVT episodes. At least one VT therapy and one FVT therapy should be programmed to a maximum energy cardioversion.

Progressive Episode Therapies – If Progressive Episode Therapies is turned on, the device may skip programmed ATP therapies and deliver cardioversion to ensure that each therapy delivered during an ongoing episode is at least as aggressive as the previous (see page 139).

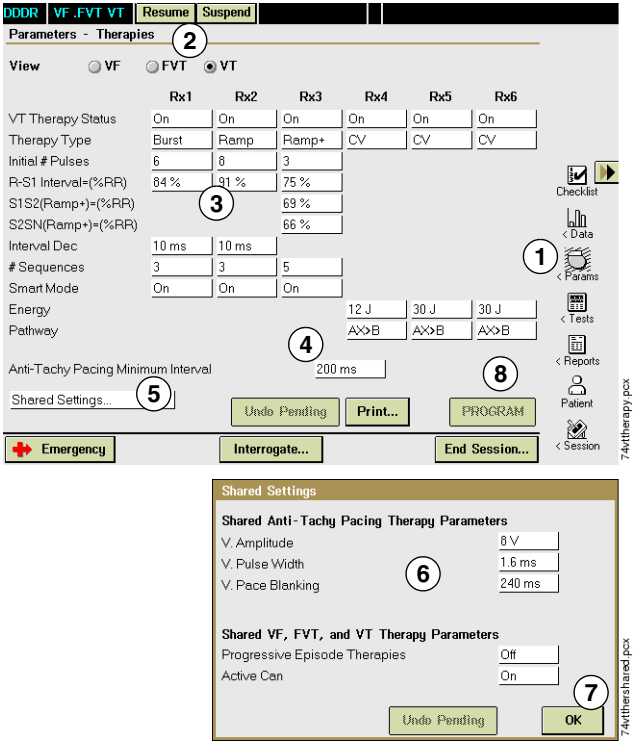
Restrictions

Review the following information before programming ATP therapy parameters.

Cardioversion therapies for FVT – You cannot program all FVT therapies as ATP therapies. If any FVT therapies are on, then at least one of them must be programmed to cardioversion (any energy).

Therapy aggressiveness – VT and FVT therapies must be programmed to be increasingly aggressive. For example, you cannot program one VT therapy to cardioversion and a subsequent VT therapy to an ATP therapy. Likewise, a VT cardioversion therapy cannot be followed by another VT cardioversion therapy with a lower energy setting.

How to program ATP therapies



1. Select Params > Therapies.
2. Select [VT] or [FVT].
3. For each ATP therapy, set Therapy Type to Burst, Ramp, or Ramp+ and set the therapy parameters as desired.
4. Select the desired value for the Anti-Tachy Pacing Minimum Interval.
5. Select Shared Settings... .
6. Select the desired values for V. Amplitude, V. Pulse Width, and V. Pace Blanking.
7. Select [OK].
8. Select [PROGRAM].

Details about ATP therapies

All antitachycardia pacing (ATP) therapies have the following characteristics:

- The pulse width, amplitude, and post-pace blanking period for antitachycardia pacing pulses are the same for all ATP therapies but are programmed separately from the bradycardia pacing pulse widths, amplitudes, and pace blanking periods. ATP pacing parameters are programmed from the Shared Settings parameter screen.
- The ATP pacing interval is rate adaptive to the average of the last four intervals prior to FVT and VT detection or redetection. However, ATP pulses are never delivered at less than the programmed minimum pacing interval. If the calculated interval is shorter than the programmed minimum, the pulses are delivered at the programmed minimum interval.
- ATP therapies cannot be delivered as programmed if the tachycardia is too fast. See “Rate limited ATP therapies” on page 125.
- If the device redetects the original arrhythmia after an ATP sequence, it delivers the next ATP sequence. If a different arrhythmia is redetected, the therapy is designated unsuccessful, and the device delivers the next programmed therapy for the current arrhythmia.

Rate limited ATP therapies

Antitachycardia pacing pulses are never delivered at less than the programmed minimum pacing interval. If the tachycardia rate is too fast, the device uses the following two algorithms:

- If the intrinsic tachycardia interval is less than or equal to the programmed minimum pacing interval, it is impossible for the device to deliver an ATP therapy that is faster than the intrinsic rate. The device cancels the rest of the ATP therapy and skips to the next programmed cardioversion therapy. If no cardioversion therapy is programmed, no therapy is delivered.
- If all the intervals of an ATP therapy sequence are delivered at the minimum interval, the therapy is fully rate limited. The device cancels the rest of the ATP therapy and skips to the next programmed therapy (or the next programmed cardioversion therapy, if FVT was detected).

Tachycardia accelerated by an ATP therapy

After delivering each ATP therapy sequence, the device monitors for an outcome. If the tachycardia accelerates to a faster arrhythmia, or if VT Acceleration occurs,[1] the remaining sequences of the pacing therapy are not delivered. Instead, the device delivers the next programmed therapy for the new arrhythmia.

Burst pacing therapy

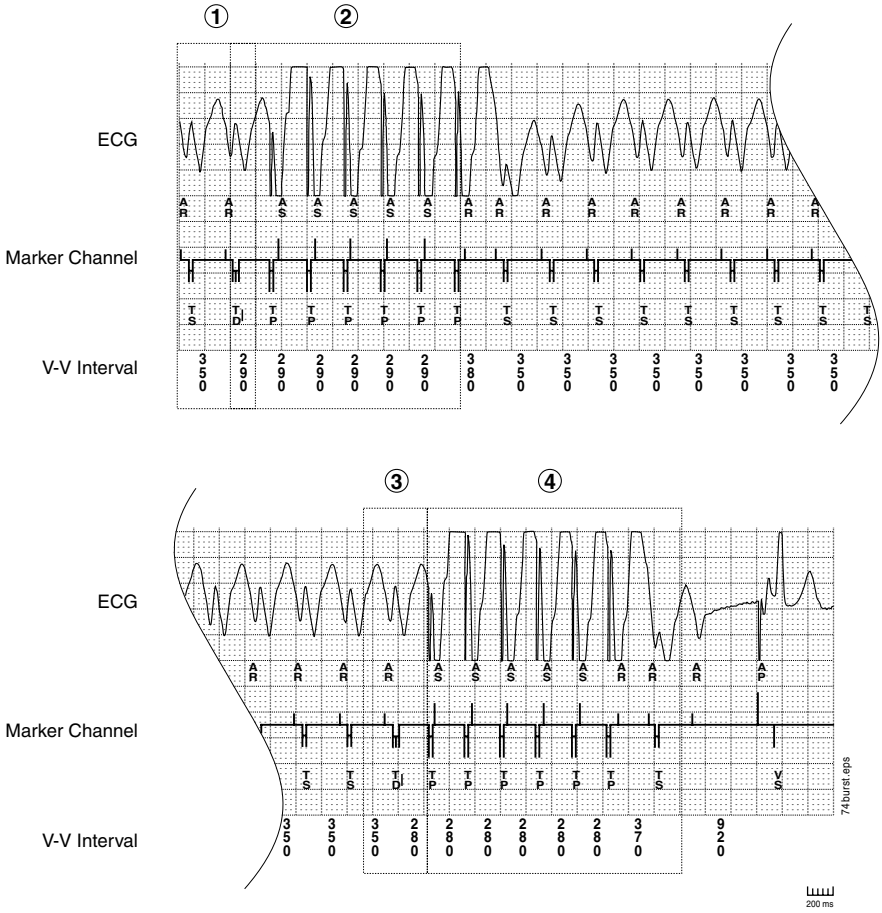
The pacing interval for the first Burst sequence is a calculated percentage of the tachycardia cycle length. Each pulse in the sequence is delivered at the same interval. Each time the tachycardia is redetected after an unsuccessful sequence, the device applies the programmed Burst percentage to the new cycle length, and then subtracts the programmed interval decrement (once per sequence) to calculate the pacing interval for the next Burst sequence.

Note: The Burst pacing therapy is delivered in VOO pacing mode.

In Figure 7-5, two Burst therapy sequences are delivered. The second therapy sequence terminates the VT.

[1] See “VT acceleration” on page 87.

Figure 7-5. Device delivers two sequences of Burst pacing therapy



1 The device detects VT.

2 The first Burst sequence is delivered with a pacing interval of 290 ms but fails to terminate the VT.

3 The device redetects VT.

4 The second Burst sequence is delivered with a pacing interval of 280 ms (the Interval Decrement is set to 10 ms per sequence) and terminates the VT.

Ramp pacing therapy

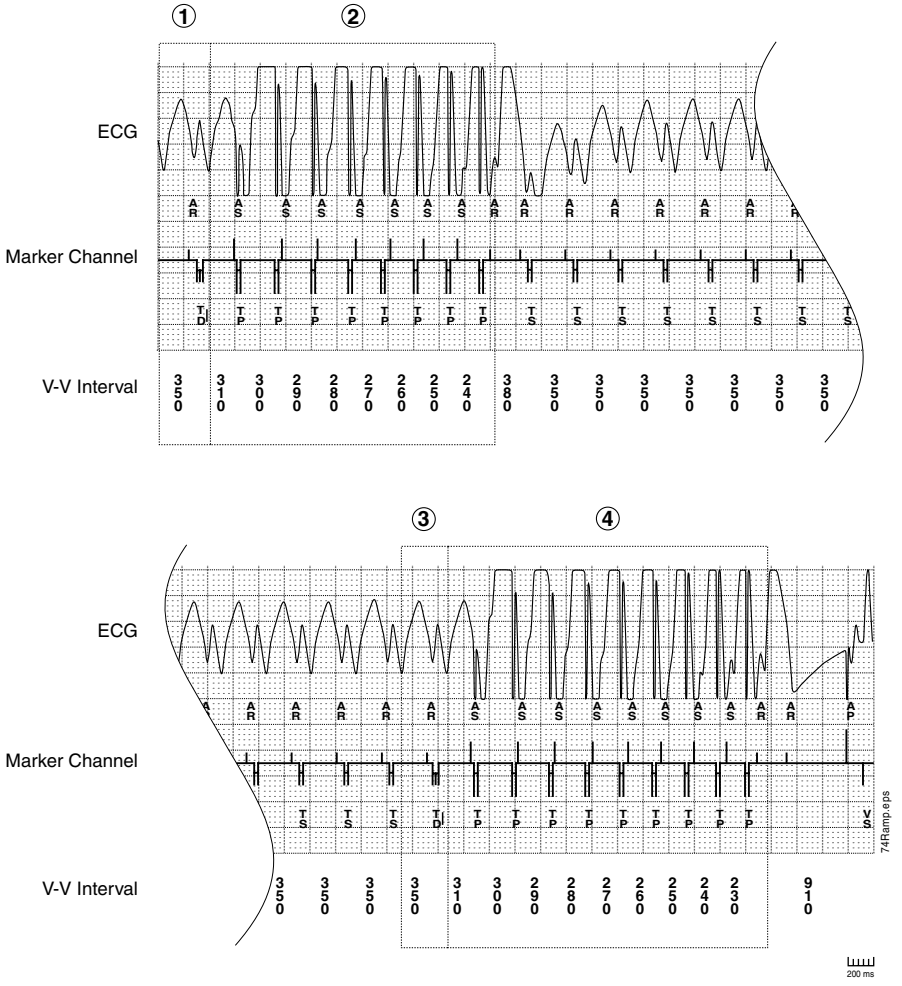
The first pulse of each Ramp sequence is delivered at a calculated percentage of the current tachycardia cycle length. Each remaining pulse in that sequence is then delivered at progressively shorter intervals by subtracting, per pulse, the programmed interval decrement.

Each time the tachycardia is redetected after an unsuccessful sequence, the device applies the programmed Ramp percentage to the new cycle length to calculate the initial pacing interval for the next sequence. Each sequence adds one pacing pulse per sequence.

Sensed ventricular events are counted as individual pulses of the Ramp sequence, even though they are not output pulses. Whenever a sensed event inhibits the scheduled Ramp Pacing VVI pulse, the next pulse is scheduled at the calculated or minimum interval.

In Figure 7-6, two Ramp therapy sequences are delivered. The second therapy sequence terminates the VT.

Figure 7-6. Device delivers two sequences of Ramp pacing therapy



1 The device detects VT.

2 The first Ramp sequence is delivered with an initial pacing interval of 310 ms, and decrements 10 ms per pulse, but fails to terminate the VT after eight pulses.

3 The device redetects VT.

4 The second Ramp sequence is delivered with an initial pacing interval 310 ms, decrements the pacing interval 10 ms per pulse, and terminates the VT after nine pulses.

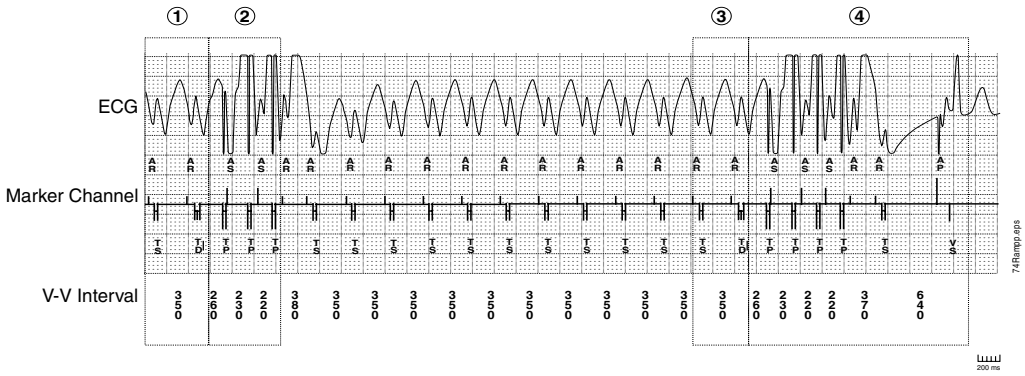
Ramp+ pacing therapy

The first pulse of each Ramp+ sequence occurs at a programmed percentage of the tachycardia cycle length, timed from the sensed event that fulfills tachycardia detection. The second pulse interval is calculated using the S1-S2 percentage. Any remaining pulses in the sequence are delivered at the S2-SN percentage.[1]

If the tachycardia is redetected, the device applies the programmed percentages to the new cycle length to calculate the pacing intervals for the next Ramp+ sequence. Each sequence adds one pacing pulse per sequence.

In Figure 7-7, two Ramp+ therapy sequences are delivered. The second therapy sequence terminates the VT.

Figure 7-7. Device delivers two sequences of Ramp+ pacing therapy



1 The device detects VT.

2 The first Ramp+ sequence consists of three pacing pulses with intervals of 260, 230, and 220 ms. The VT is not terminated.

3 The device redetects VT.

4 The second Ramp+ therapy repeats the first three intervals and adds another pulse with a 220 ms interval, which terminates the VT.

[1] Ramp + pacing therapy is delivered in VOO mode.

Treating VT and FVT with cardioversion

The device can respond to a VT or FVT episode by delivering antitachycardia pacing or cardioversion therapy to the patient's heart. Cardioversion, like defibrillation, is intended to terminate the episode by simultaneously depolarizing the heart tissue and restoring the patient's normal sinus rhythm. However, cardioversion requires that the device synchronize the therapy to an arrhythmic ventricular event.

You can program the device to deliver a sequence of up to six VT therapies and six FVT therapies, and you can select cardioversion for some or all of these therapies. You can set the energy and pathway parameters individually for each cardioversion therapy.

See details about cardioversion therapy on page 133.

Parameters

* Medtronic nominal setting

VT (or FVT) Therapy Status – Turns a specific VT or FVT therapy on or off.	On* or Off
Therapy Type – Cardioversion or ATP therapy to treat VT or FVT episodes (choose CV to enable cardioversion).	CV, Burst, Ramp, Ramp+
Energy (J) – Amount of energy delivered to the heart by the therapy.	0.4, 0.6, . . ., 1.8, 2, 3, . . ., 16, 18, 20, . . ., 30*
Pathway – Direction the electrical current flows through the heart.	AX>B* or B>AX
Active Can – Option to select the device case as an active electrode for delivering defibrillation and cardioversion therapies.	On*, Off

Considerations

Review the following information before programming cardioversion parameters.

△ **Caution:** If the Active Can feature is turned off, the device delivers defibrillation and cardioversion therapies between the RV (HVB) and SVC (HVX) electrodes only. To ensure the device can deliver defibrillation and cardioversion therapies, make sure a supplementary HVX electrode is implanted and connected to the device before turning Active Can off.

Active Can – The programmed setting for Active Can applies to the following high voltage operations:

- automatic, manual, and emergency cardioversion
- automatic, manual, and emergency defibrillation
- T-shock inductions

Energy – Programming the cardioversion therapy energy to an optimized value (lower than the maximum energy but high enough to terminate VT) can expedite delivery and help preserve battery longevity. However, at least one VT therapy and one FVT therapy should be programmed to a maximum energy cardioversion.

Progressive Episode Therapies – If Progressive Episode Therapies is turned on, the device may deliver a high voltage therapy at a higher energy level than is programmed. This ensures that each therapy delivered during an ongoing episode is at least as aggressive as the previous therapy (see page 139).

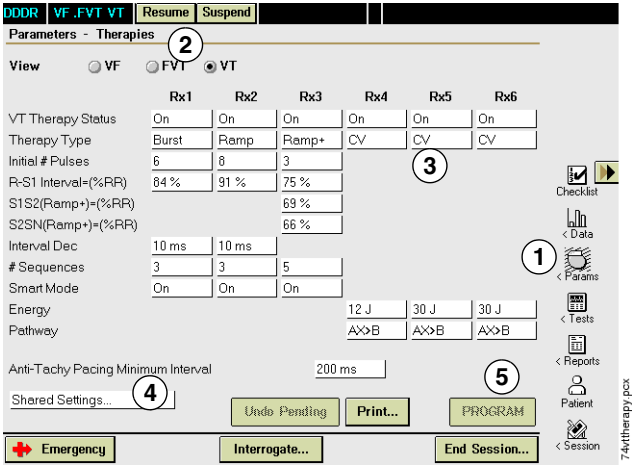
Restrictions

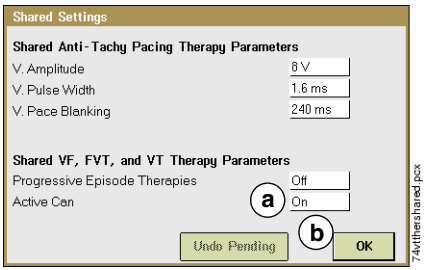
Review the following information before programming cardioversion parameters.

Cardioversion therapies for FVT – If FVT therapies are on, then at least one must be programmed to cardioversion (at any energy).

Therapy aggressiveness – VT and FVT therapies must be programmed to be increasingly aggressive. For example, you cannot program one VT therapy to cardioversion and a subsequent VT therapy to an ATP therapy. Likewise, a VT cardioversion therapy cannot be followed by another VT cardioversion therapy with a lower energy setting.

How to program cardioversion therapies





1. Select Params > Therapies.
2. Select [VT] or [FVT].
3. For each cardioversion therapy, set Therapy Type to CV and set Energy and Pathway values as desired.
4. To change the Active Can parameter value, select Shared Settings... .
   a. Select a value for Active Can.
   b. Select [OK].
5. Select [PROGRAM].

Details about cardioversion therapy

When a VT or FVT episode is detected and the next programmed therapy is a cardioversion, the device begins charging its high voltage capacitors and attempts to confirm the continued presence of the tachyarrhythmia. If the arrhythmia terminates, the device cancels the therapy.

If the arrhythmia is still present when the capacitors are charged to the programmed energy, the device delivers the cardioversion pulse synchronized to a sensed ventricular event. If synchronization is not possible, the device cancels the therapy.

Capacitor charging period

To deliver a cardioversion therapy, the device must first charge its high voltage capacitors to the programmed energy. The length of time required to charge the capacitors depends on the programmed energy, battery depletion, and the length of time since the last capacitor formation. See Table 1-6 on page 10 for typical full energy capacitor charging periods.

Delivery pathway electrodes

The device can deliver cardioversion therapies via the following high voltage electrodes:

- Can (HVA) – device can
- RV (HVB) – RV coil
- SVC (HVX) – optional electrode (for example, an SVC coil)

If an optional electrode is used, you can disable the Active Can feature. If you do so, the device delivers cardioversion therapies between the RV (HVB) and SVC (HVX) electrodes only.

Energy

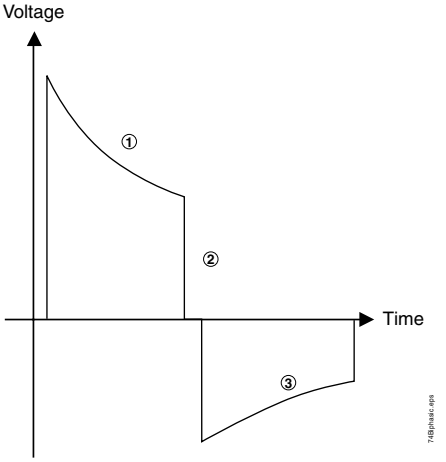
The device can deliver up to 30 joules,[1] which corresponds to a stored energy of 35 joules.[2] For a comparison of delivered and stored energy levels, see Table 1-7 on page 11. The energy level is programmed independently for each cardioversion therapy.

[1] Delivered energy of biphasic waveform into 75 ohms.
[2] Derived from the peak capacitor voltage, which is always greater than the energy delivered by the device.

Waveform

The device delivers cardioversion therapies using a biphasic waveform, which consists of two phases. In the first phase, current is delivered until the pulse decays to 50% of its original voltage. The device then truncates the phase and reverses the current pathway for the second phase. When the second phase of the pulse decays to 50% of its original voltage, the device truncates the pulse.

Figure 7-8. Cardioversion pulse waveform



1 The first segment of the pulse decays to 50% of the original voltage.

2 The pulse is truncated and the polarity is reversed.

3 The second segment of the pulse decays to 50% and then is truncated.

Confirming VT or FVT after detection

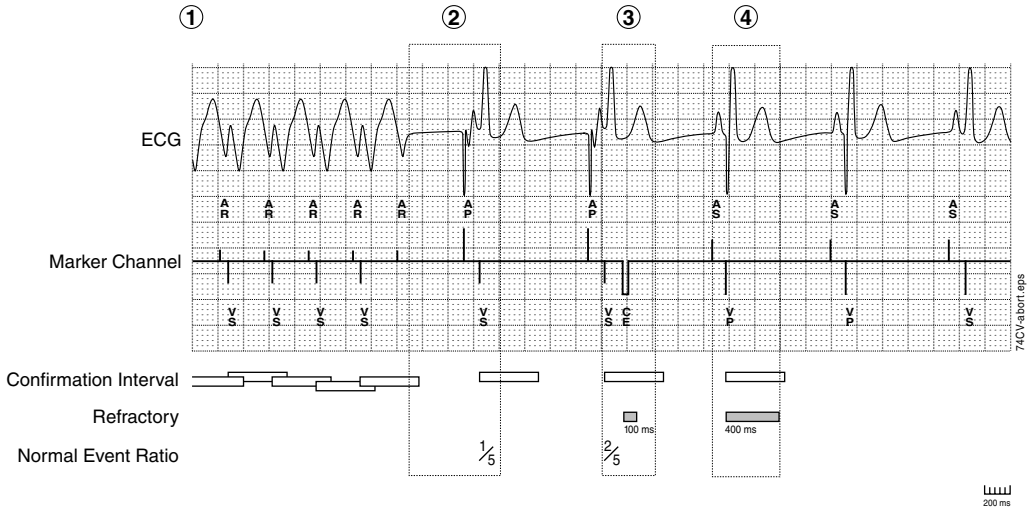
When the device begins charging its capacitors for a cardioversion therapy, it monitors the cardiac rhythm to ensure that the arrhythmia remains present before delivering the therapy.

The device confirms the continued presence of the tachyarrhythmia using a sequence of confirmation intervals, each lasting 60 ms plus the programmed VT Interval.[1] It classifies any ventricular event that occurs within the confirmation interval as “arrhythmic” and any events after the interval as “normal.”

[1] Or VF Interval, if VT Detection is set to Off or Monitor.

On each ventricular event during charging, the device reviews the last five events since charging started. If four of the last five ventricular events were normal, the device stops charging and cancels the therapy (see Figure 7-9).

Figure 7-9. Cardioversion therapy cancelled when VT terminates spontaneously



1 The device has detected VT, is charging its capacitors for cardioversion, and is confirming the arrhythmia using a confirmation interval of 460 ms (VT Interval + 60 ms).

2 The VT spontaneously terminates, and normal sinus rhythm resumes.

3 The charging period ends, and synchronization starts. At this point, the device stops the confirmation process and disregards the normal event ratio. Any normal event after charging will abort the cardioversion therapy.

4 The cardioversion therapy aborts when a normal event occurs during synchronization.

Synchronizing cardioversion after charging

Once charging ends, the device attempts to synchronize the cardioversion therapy to a qualified ventricular event but also continues to confirm the presence of the arrhythmia. An event qualifies for delivery if it is non-refractory and meets one of the following conditions:

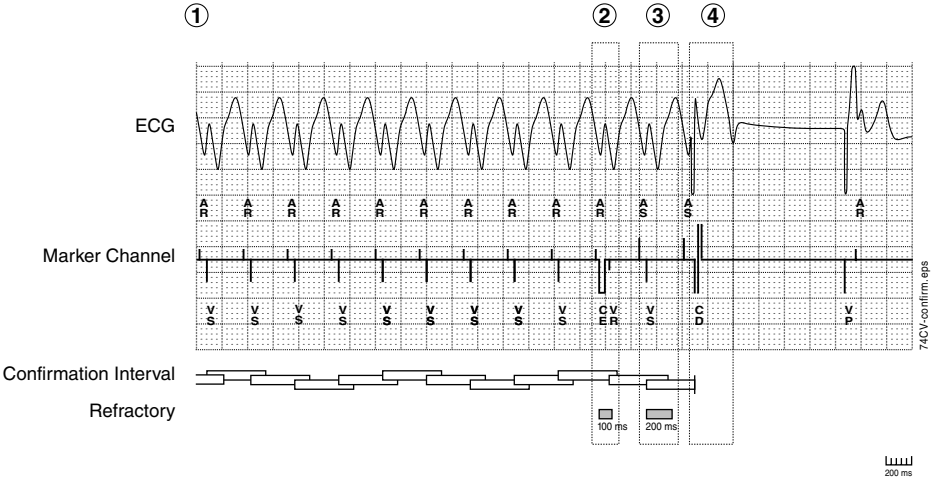
- the second arrhythmic ventricular event and is outside an AVP interval
- the third arrhythmic ventricular event

The device confirms the presence of the detected arrhythmia differently after charging than it does during charging. After charging, the device aborts the cardioversion therapy if one of the following events occur:

- a normal ventricular event
- three consecutive V-V intervals less than 200 ms

The device continues to attempt to synchronize until it delivers the cardioversion therapy or it fails to confirm the presence of the arrhythmia and cancels the therapy.

Figure 7-10. VT confirmed and cardioversion synchronized to an arrhythmic event



1 The device has detected VT, is charging its capacitors for cardioversion, and is confirming the arrhythmia using a confirmation interval of 460 ms (VT Interval + 60 ms).

2 The device completes charging and starts a 100 ms refractory period, while continuing confirmation. A refractory event occurs, and the device starts a new confirmation interval.

3 An arrhythmic ventricular event occurs, and the device starts a 200 ms refractory period.

4 On the second arrhythmic event after charging, the device delivers the cardioversion therapy.

Refractory events – During the synchronization process, the device classifies events as refractory if they occur during any of the following refractory periods:

- 400 ms after charging starts
- 400 ms after a ventricular or atrial paced event
- 200 ms after a ventricular sensed event
- 100 ms after charging ends (if the ventricular interval is shorter than the confirmation interval)

AVP events – The device postpones a defibrillation or cardioversion therapy scheduled to be delivered during an Atrial Vulnerable Period (AVP) until the next qualifying event. The AVP is a 250 ms interval, starting 150 ms after a sensed atrial event, during which a high voltage pulse might induce an atrial tachyarrhythmia. AVP operation can postpone the therapy for only one event during synchronization.

Bradycardia pacing during cardioversion

On the first ventricular event after charging, the device changes the pacing mode to VVI and sets the pacing interval as follows:

- If the programmed pacing mode is ODO, the device uses a 2000 ms (30 ppm) pacing interval.
- If the programmed pacing mode is DDD, DDI, VVI, AAI, DDDR, DDIR, VVIR, or AAIR, the device uses the pacing interval that was in effect before charging.

After a cardioversion therapy

Immediately after delivering a cardioversion therapy, the device starts both of the following operations:

- a post shock blanking period of 520 ms in each chamber
- a VVI pacing cycle at 50 ppm (escape interval of 1200 ms)

After the first ventricular event, the programmed bradycardia pacing mode resumes, using the Post Shock Pacing parameters. See “Providing pacing after high voltage therapies” on page 196.

The device monitors for either the end of the episode or redetection.

After a cancelled cardioversion therapy

If the device cancels a cardioversion therapy, it reverts immediately to the programmed bradycardia pacing settings (not the Post-Shock pacing parameters).

The device resumes monitoring for arrhythmias after the next paced or sensed ventricular event. If the device detects the same arrhythmia again, it attempts to synchronize and deliver the same therapy. However, if the episode ends, it resumes normal detection.

Note: If the device cancels the cardioversion therapy, leaving energy stored on the capacitors, the delivered energy of the next high voltage therapy may be higher than the programmed value.

Optimizing therapy with Smart Mode and Progressive Episode Therapies

Smart Mode disables an ATP therapy that has been unsuccessful in four consecutive episodes so that the device can treat subsequent episodes more quickly with therapies that have been effective. Therapies disabled by Smart Mode are displayed on the therapy parameters screens with the Off-SM indicator.

Progressive Episode Therapies skips therapies or modifies high voltage energy levels to ensure that each therapy delivered during an episode is at least as aggressive as the previous therapy.

For more information, see

- "Details about Smart Mode" on page 141
- "Details about Progressive Episode Therapies" on page 142

Parameters

* Medtronic nominal setting

Smart Mode – Disables a programmed ATP therapy if it has been unsuccessful in terminating tachyarrhythmias.	On or Off*
Progressive Episode Therapies – Ensures each therapy delivered during an episode is at least as aggressive as the previous therapy.	On or Off*

Considerations

Review the following information before programming the Smart Mode and Progressive Episode Therapies parameters.

Smart Mode and therapy selection – If Smart Mode disables an ATP therapy, either select a different therapy or modify the current therapy settings to improve its effectiveness.

Smart Mode unsuccessful therapy count – The device resets its count of unsuccessful therapies if any parameter of any automatic therapy is reprogrammed (including ATP, VF, FVT, or VT therapies).

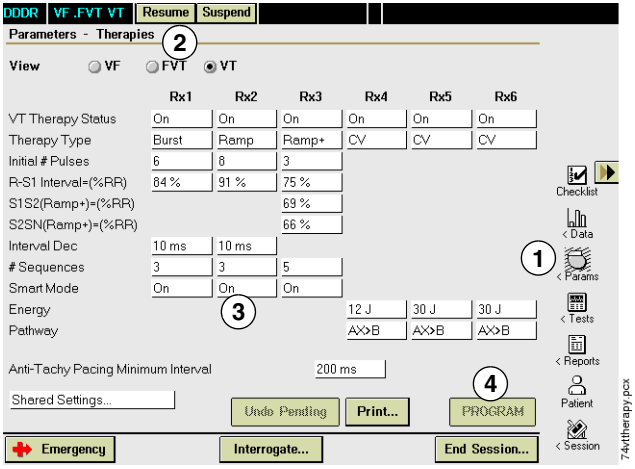
Progressive Episode Therapies – If Progressive Episode Therapies is on, the device may skip programmed ATP therapies and deliver cardioversion, or it may deliver a high voltage therapy at a higher energy level than is programmed. This ensures that each therapy delivered during an ongoing episode is at least as aggressive as the previous therapy.

Restrictions

Review the following information before programming Smart Mode.

Smart Mode – You can turn on Smart Mode for only the first four VT or FVT therapies for which an ATP therapy is selected.

How to program Smart Mode



1. Select Params > Therapies.
2. Select [VT] or [FVT].
3. For each enabled ATP therapy, choose a value for the Smart Mode parameter.
4. Select [PROGRAM].

Details about Smart Mode

When Smart Mode is on for an ATP therapy, the device monitors the success of that therapy. If there are four consecutive episodes in which all sequences of the ATP therapy are delivered but are unsuccessful, the device disables that ATP therapy. Table 7-2 shows an example of Smart Mode operation.

An ATP therapy disabled by Smart Mode is designated by "Off-SM" in the counter data and parameter screens and reports. You can re-enable a therapy disabled by Smart Mode by setting the Therapy Status parameter for that therapy to On.

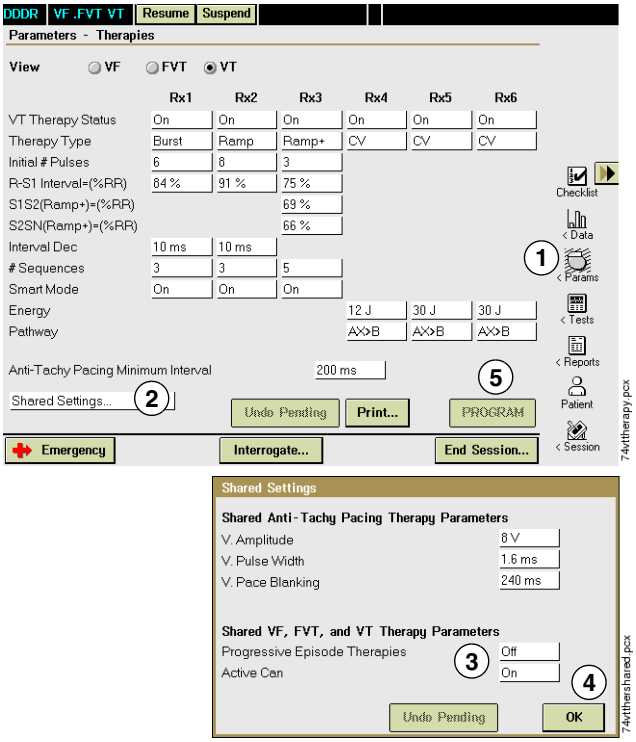
Table 7-2. Smart Mode operation example

Episode	Therapy sequence	Comments
1. VT	VT Rx 1 → VT Rx 2	VT Rx 1 unsuccessful.
2. VT → VF	VT Rx 1 → VF Rx 1	VT Rx 1 unsuccessful in second consecutive episode.
3. VT	VT Rx 1 → VT Rx 2	VT Rx 1 unsuccessful in third consecutive episode.
4. VT	VT Rx 1 → VT Rx 2	VT Rx 1 unsuccessful in fourth consecutive episode: **Smart Mode disables VT Rx 1.**
5. VT	VT Rx 2	Device delivers VT Rx 2 (skipping the disabled VT Rx 1).

Note: The device resets the count of unsuccessful therapy attempts for an ATP therapy if any of the following situations occur:

- The ATP therapy successfully treats an arrhythmia.
- Any parameter of any automatic therapy is re-programmed (including ATP, VF, FVT, or VT therapies).
- A VT, FVT, *or VF* episode occurs during which the therapy is not delivered.

How to program Progressive Episode Therapies



To program Progressive Episode Therapies:

1. Select Params > Therapies.
2. Select Shared Settings... .
3. Select a value for the Progressive Episode Therapies parameter.
4. Select [OK].
5. Select [PROGRAM].

Details about Progressive Episode Therapies

Progressive Episode Therapies ensures that, if a therapy is unsuccessful, all subsequent therapies in an ongoing episode are at least as aggressive as preceding therapies. Therapies are ranked by aggressiveness as follows:

- Defibrillation therapies are considered more aggressive than cardioversion therapies and are ranked by energy level.
- Cardioversion therapies are considered more aggressive than ATP therapies and are ranked by energy level.
- ATP therapies are considered least aggressive and are ranked equally in aggressiveness.

When a therapy is delivered, Progressive Episode Therapies makes therapies in the slower detection zones unavailable for the remainder of the episode. For example, if a VF defibrillation therapy is delivered, only VF therapies are available for the remainder of the episode.

If a defibrillation or cardioversion therapy is delivered, Progressive Episode Therapies makes any ATP therapies unavailable for the remainder of the episode. For example, if a VT cardioversion therapy is delivered, and the FVT therapies contain an ATP therapy, that ATP therapy is skipped if the arrhythmia is redetected as FVT.

If a defibrillation or cardioversion therapy is unsuccessful, and the next scheduled therapy is a lower energy therapy, Progressive Episode Therapies does not skip that therapy. Instead, it resets the energy value for the next therapy to that of the last delivered therapy.

Note: The device does not suspend VT detection for 17 events following a defibrillation therapy that is delivered as a result of Progressive Episode Therapies operation.

Key terms

Active Can – option to select the device case as an active electrode for delivering defibrillation and cardioversion therapies.

Antitachycardia Pacing (ATP) – therapies for VT or FVT that deliver rapid sequences of pacing pulses to terminate the VT. See also Burst, Ramp, and Ramp+.

Atrial Vulnerable Period (AVP) – 250 ms synchronization interval, starting 150 ms after a sensed atrial event, when a ventricular shock could trigger an atrial tachyarrhythmia.

biphasic – high voltage therapy waveform in which most of the energy is delivered from anode to cathode, and the remaining energy is delivered from cathode to anode.

Burst pacing – ATP therapy that delivers sequences of pacing pulses with an interval that is a programmable percentage of the tachycardia cycle length. With each sequence of Burst pacing delivered, the device shortens the pacing interval by a programmable interval.

cardioversion – therapy designed to treat VT and FVT episodes with a programmable energy shock, which must be synchronized to an arrhythmic ventricular event.

charging period – time for the device to store the programmed energy (charge) in its high voltage capacitors.

Confirm VF after initial detection – see VF confirmation.

current pathway – electrical route across which defibrillation and cardioversion therapies are delivered. A therapy can be separately programmed to be delivered from the Can (HVA) electrode and/or SVC (HVX) electrode (depending on the implanted system and the Active Can setting) to the RV (HVB) electrode, or vice versa.

defibrillation – therapy designed to treat VF episodes with a programmable energy shock. Unless VF confirmation is active, the device delivers a defibrillation therapy even if it cannot synchronize to a ventricular event.

HVA/HVB/HVX – high voltage electrode identifiers. In a standard lead configuration, HVA is the titanium body of the device; HVB is the RV electrode; and HVX is the SVC electrode.

Progressive Episode Therapies – skips therapies or modifies high voltage energy levels to ensure that each therapy delivered during an episode is at least as aggressive as the previous therapy.

Ramp pacing – ATP therapy that delivers pacing pulses with progressively shorter pacing interval per pulse. Each sequence of Ramp pacing delivered during a therapy includes an additional pacing pulse.

Ramp+ pacing – ATP therapy that delivers pacing pulses at programmable intervals that are based on percentages of the tachycardia cycle length. Each sequence of Ramp+ pacing delivered during a therapy includes an additional pacing pulse.

sequence – one programmable set of Burst, Ramp, or Ramp+ pacing pulses.

Smart Mode – disables an ATP therapy that has been unsuccessful in four consecutive episodes so that the device can treat subsequent episodes more quickly with therapies that have been effective.

synchronization – period during defibrillation and cardioversion therapies when the device attempts to deliver the therapy shock simultaneously with a sensed ventricular event.

therapy – treatment for a detected arrhythmia. A therapy consists of a cardioversion or defibrillation shock or a series of ATP sequences.

VF confirmation – programmable option that causes the device, for the first defibrillation therapy during a VF episode, to confirm the presence of VF during and after charging and to synchronize the therapy to an arrhythmic ventricular event.

Treating bradycardia

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Providing basic pacing therapy

The device provides pacing therapies to support pacemaker dependent patients, to correct certain arrhythmias, and to ease the heart back into an intrinsic rhythm after high voltage therapy.

Basic pacing is programmed by selecting a pacing mode and pacing rates. Additional parameters are also used to control and enhance pacing based on the pacing mode selected.

See details about basic pacing modes on page 152.

Parameters

* Medtronic nominal setting

	Atrial Lead	Ventricular Lead
Amplitude (V) – Voltage setting for pacing pulse.	0.5, 1, . . ., 3*, 3.5, 4, 5, 6 Modes: DDDR, DDD, DDIR, DDI, AAIR, AAI, DOO	0.5, 1, . . ., 3*, 3.5, 4, 5, 6 Modes: DDDR, DDD, DDIR, DDI, VVIR, VVI, DOO, VOO
Pace Blanking (ms) – Time interval during which sensing is disabled after a pacing pulse. This value is also used during post-shock blanking.	150, 160, . . ., 200*, . . ., 250 Modes: DDDR, DDD, DDIR, DDI, AAIR, AAI	150, 160, . . ., 200*, . . ., 440 Modes: DDDR, DDD, DDIR, DDI, VVIR, VVI
Pulse Width (ms) – duration setting for pacing pulse.	0.03, 0.06, 0.1, 0.2, 0.3, 0.4*, . . ., 1.6 Modes: DDDR, DDD, DDIR, DDI, AAIR, AAI, DOO	0.03, 0.06, 0.1, 0.2, 0.3, 0.4*, . . ., 1.6 Modes: DDDR, DDD, DDIR, DDI, VVIR, VVI, DOO, VOO
Sensitivity (mV) – setting for the minimum electrical signal sensed as an intrinsic event.	0.15, 0.3*, 0.45, 0.6, 0.9, 1.2, 1.5, 2.1 Modes: All	0.15, 0.3*, 0.45, 0.6, 0.9, 1.2 Modes: All
Mode – NBG Code[a] describes device functionality by indicating chamber paced, chamber sensed, response to sensed event, and rate response capability.		DDD, DDI, DDDR*, DDIR, AAIR, AAI, VVIR, VVI, ODO, DOO, VOO

(continued)	* Medtronic nominal setting
Lower Rate (ppm, min^{-1}) – Minimum pacing rate to maintain adequate heart rate during periods of inactivity.	30, 35, . . ., 60*, 70, 75, . . ., 150 Modes: all except ODO
Upper Sensor Rate (ppm, min^{-1}) – Maximum upper limit for the sensor-indicated rate during physical activity.	80, 85, . . ., 120*, . . ., 150 Modes: DDD,[b] DDDR, DDIR, AAIR, VVIR

[a] N=North American Society of Pacing and Electrophysiology (NASPE), B=British Pacing and Electrophysiology Group (BPEG), G=Generic Pacemaker Code

[b] Available in DDD mode only when Mode switch is programmed On.

Considerations

Review the following information before programming basic bradycardia parameters.

Sensitivity – The programmed sensitivity values apply to both tachyarrhythmia detection and bradycardia pacing. Always verify that the device senses properly during VF. If the device is not sensing or detecting properly, program detection and therapies off, and evaluate the system (making sure to monitor the patient for life-threatening arrhythmias until you enable detection and therapies again). You may need to reposition or replace the ventricular sensing lead to achieve proper sensing. See “Setting up sensing” on page 61.

Pulse Width and Amplitude – To help maintain consistent capture, these parameters are independently programmable for atrial and ventricular pacing and post-shock pacing. Consider the following information when programming pulse width and amplitude parameters:

- Pacing pulses must be delivered at an adequate safety margin above the stimulation thresholds.
- The pulse width and amplitude settings affect the longevity of the device, particularly if the patient requires a high percentage of bradycardia pacing therapy.
- Pulse width and amplitude settings can affect cross-chamber sensing. If you set the pulse width and amplitude values too high, pacing in one chamber may be sensed in the other chamber, which could cause inappropriate inhibition of pacing.

- A separately programmable set of pacing parameters is used after delivery of a high voltage therapy. See “Providing pacing after high voltage therapies” on page 196.

Pacing Mode – Determine the appropriate pacing mode based on the patient’s current cardiac condition (see Table 8-1).

Table 8-1. Determining the appropriate pacing mode

Reliable pacing and sensing in atrium?	Adequate AV conduction?	Adequate SA node function?	Suggested mode
NO [a]			VVIR, VVI
YES	NO [b]	NO	DDDR
YES	NO [b]	YES	DDDR, DDD
YES	YES	NO	DDDR, DDIR
YES	YES	YES	DDDR, DDD, DDIR, DDI

[a] Example: persistent atrial fibrillation or unexcitable atrium

[b] Example: complete or transient AV block

Pace Blanking – Pace blanking can affect same chamber pacing. If you program the pace blanking periods too short, pacing output artifacts may be sensed which could cause inappropriate inhibition of pacing.

Programming the atrial pace blanking period to a value greater than 240 ms increases the risk for atrial competition and under-sensing at high rates.

Upper Sensor Rate in DDD mode – The Upper Sensor Rate is used in DDD mode only if Mode Switch is on. However, the Upper Sensor Rate must be programmed to a value less than or equal to the Upper Tracking Rate.

Note: Upper Sensor Rate can be programmed higher, lower, or equal to the Upper Tracking Rate when in DDDR mode, except when Mode Switch is programmed On.

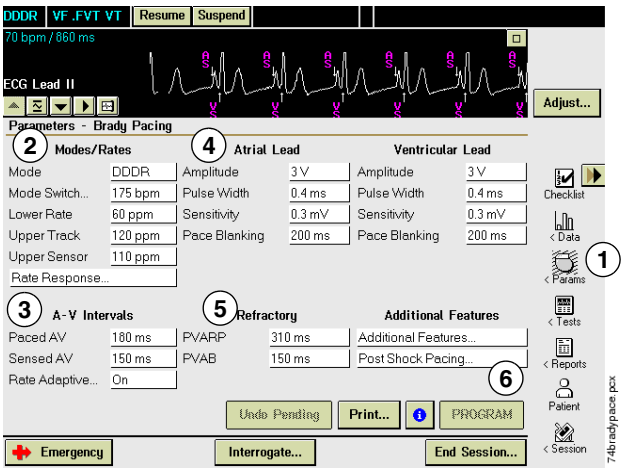
Upper rates and refractory periods – A combination of high Upper Sensor Rate, high Upper Tracking Rate, and a long refractory period may result in competitive atrial pacing if Non-Competitive Atrial pacing is not enabled. See “Preventing competitive atrial pacing” on page 184.

Restrictions

Review these programming restrictions before programming basic bradycardia parameters.

Bradycardia pacing and tachyarrhythmia detection – To ensure reliable ventricular tachyarrhythmia detection, the device software regulates the programmable values available for bradycardia pacing and tachyarrhythmia detection. See “Parameter interlocks” on page 386.

How to program bradycardia pacing parameters



1. Select Params icon > Brady Pacing.
2. Select the pacing Mode.
3. Set the A-V interval settings for Paced AV and Sensed AV, if available for the selected mode.
4. Set the desired atrial and ventricular Amplitude, Pulse Width, Sensitivity, and Pace Blanking for pacing, if available for the selected mode.
5. Set the PVARP and PVAB settings, if available for the selected mode.
6. Select [PROGRAM].
   For additional Brady pacing programming instructions, refer to the following sections in this chapter.

Details about basic bradycardia pacing

Table 8-2 lists pacing parameters and features available based on the selected pacing mode.

Table 8-2. Bradycardia pacing parameters available for selected pacing modes

	DDDR	**DDD**	**DDIR**	**DDI**	**AAIR**	**AAI**	**VVIR**	**VVI**	**DOO**	**VOO**	**ODO**[a]
atrial amplitude/ post-shock atrial amplitude	DDDR	DDD	DDIR	DDI	AAIR	AAI			DOO		
atrial pace blanking[b]	DDDR	DDD	DDIR	DDI	AAIR	AAI					
atrial pulse width/ post-shock atrial pulse width	DDDR	DDD	DDIR	DDI	AAIR	AAI			DOO		
atrial refractory period					AAIR	AAI					
atrial sensitivity	DDDR	DDD	DDIR	DDI	AAIR	AAI	VVIR	VVI	DOO[c]	VOO	ODO
lower rate	DDDR	DDD	DDIR	DDI	AAIR	AAI	VVIR	VVI	DOO	VOO	
mode switch	DDDR	DDD									
non-competitive atrial pacing	DDDR	DDD									
paced AV interval	DDDR	DDD	DDIR	DDI					DOO		
PMT intervention	DDDR	DDD									
PVAB	DDDR	DDD	DDIR	DDI							
PVARP	DDDR	DDD	DDIR	DDI							
PVC response	DDDR	DDD	DDIR	DDI							
rate adaptive AV	DDDR	DDD	DDIR	DDI[d]							
rate response	DDDR	DDD[e]	DDIR		AAIR		VVIR				
sensed AV interval	DDDR	DDD									
sensor-varied PVARP setting	DDDR		DDIR	DDI[d]							
single chamber hysteresis						AAI		VVI			
upper sensor rate	DDDR	DDD[e]	DDIR		AAIR		VVIR				
upper tracking rate	DDDR	DDD									
ventricular amplitude/post-shock ventricular amplitude	DDDR	DDD	DDIR	DDI	AAIR	AAI	VVIR	VVI	DOO	VOO	ODO
ventricular pace blanking[b]	DDDR	DDD	DDIR	DDI			VVIR	VVI			

Table 8-2. Bradycardia pacing parameters available for selected pacing modes (continued)

	DDDR	**DDD**	**DDIR**	**DDI**	**AAIR**	**AAI**	**VVIR**	**VVI**	**DOO**	**VOO**	**ODO**[a]
ventricular pulse width/ post-shock ventricular pulse width	DDDR	DDD	DDIR	DDI	AAIR	AAI	VVIR	VVI	DOO	VOO	ODO
ventricular rate stabilization	DDDR	DDD	DDIR	DDI			VVIR	VVI			
ventricular safety pacing	DDDR	DDD	DDIR	DDI							
ventricular sensitivity	DDDR	DDD	DDIR	DDI	AAIR	AAI	VVIR	VVI	DOO[c]	VOO[c]	ODO

[a] Brady pacing is disabled in ODO mode.

[b] The programmed value is also used for post-shock blanking.

[c] Parameter can be selected, but is not pertinent in this mode.

[d] When VRS is on.

[e] When Mode Switch is on.

For more information about

- Rate Response, Rate Adaptive AV, and Ventricular Rate Stabilization, see “Enhancing pacing for optimal cardiac output” on page 167.
- Mode switch, see “Adjusting the pacing rate with Mode Switch” on page 180.
- Non-Competitive Atrial Pacing, see “Preventing competitive atrial pacing” on page 184.
- PVC Response and PMT Intervention, see “Detecting and preventing pacemaker-mediated tachycardia” on page 189.
- Ventricular Safety Pacing, see “Providing Ventricular Safety Pacing” on page 193.

Dual-chamber pacing

Dual chamber pacing modes rely on the basic pacing parameters and several additional atrial parameters.

See details about dual-chamber pacing on page 156.

Parameters

* Medtronic nominal setting

Mode Switch – automatically switches the pacing mode to DDIR during an atrial tachyarrhythmia.	Modes: DDDR, DDD
Enable	On, Off*
A. Detect Rate (bpm, min^{-1})	120, 125, . . ., 175*
Non-Competitive Atrial Pacing (NCAP) – delays an atrial pace scheduled to fall within the relative atrial refractory period to prevent triggering an atrial tachyarrhythmia.	Modes: DDDR, DDD
Enable	On*, Off
Interval (ms)	200, 250, 300*, 350, 400
Paced AV (ms) – time interval between a paced atrial event and the following paced ventricular event.	30, 40, . . ., 180*, . . ., 350 Modes: DDDR, DDD, DDIR, DDI, DOO
PMT Intervention – automatically detects PMT and responds by interrupting atrial tracking for one cycle.	Modes: DDDR, DDD
Enable	On, Off*
Post-Ventricular Atrial Blanking (PVAB) (ms) – sets the interval during which sensed atrial events are ignored by bradycardia pacing features.	100, 110, . . ., 150*, . . ., 310 Modes: DDDR, DDD, DDIR, DDI
Post Ventricular Atrial Refractory Period (PVARP) (ms) – prevents sensing of retrograde P-waves in DDD and DDDR modes. In DDIR and DDI modes PVARP prevents atrial inhibition from retrograde P-waves.	Varied,[a] 150, 160, . . ., 310*, . . ., 500 Modes: DDDR, DDD, DDIR, DDI

(continued)	* Medtronic nominal setting
PVC Response – detects a PVC and responds by extending the PVARP to 400 ms (if the currently programmed or Sensor-Varied PVARP is less than 400 ms)	Modes: DDDR, DDD, DDIR, DDI
Enable	On*, Off
Rate Adaptive AV – shortens the AV intervals at high atrial rates, imitating a normal heart's physiologic response by shortening AV conduction time as the heart rate increases and lengthening conduction as the heart rate decreases.	Modes: DDDR, DDD, DDIR, DDI[b]
Enable	On*, Off
Start Rate (bpm, min^{-1})	50, 55, 60*, . . ., 145
Stop Rate (bpm, min^{-1})	55, 60, . . ., 120*, . . ., 150
Minimum PAV (ms)	30, 40, . . ., 140*, . . ., 350
Minimum SAV (ms)	30, 40, . . ., 110*, . . ., 350
Sensed AV (ms) – Time interval between a sensed atrial event and the following paced ventricular event.	30, 40, . . ., 150*, . . ., 350 Modes: DDDR, DDD
Upper Tracking Rate (ppm, min^{-1}) – Maximum ventricular pacing rate in response to sensed atrial events.	80, 85, . . ., 120*, . . ., 150 Modes: DDDR, DDD
Ventricular Safety Pacing – prevents inappropriate inhibition of ventricular pacing due to cross chamber sensing of an atrial pace.	Modes: DDDR, DDD, DDIR, DDI
Enable	On,* Off

[a] The Varied setting for PVARP is not available in DDD mode.

[b] RAAV applies when VRS is programmed On.

Considerations

Review the following information before programming dual chamber pacing parameters.

Paced AV and Sensed AV – The Sensed AV should usually be programmed to a shorter duration than the Paced AV (typically 30 to 50 ms shorter). In patients with normal AV nodal conduction, AV intervals should be programmed to promote intrinsic AV conduction and ventricular depolarization.

Upper Tracking Rate – The Upper Tracking Rate should be programmed to a value less than the 2:1 block rate. See “Programming considerations for atrial rates” on page 161.

Details about dual-chamber pacing

In dual chamber modes, sensing and pacing occur in both chambers. The dual chamber pacing modes provided by the device include DDDR, DDD, DDIR, and DDI. In the DDD mode, pacing occurs at the lower rate in the absence of intrinsic atrial activity. In the DDI pacing mode, pacing always occurs at the lower rate. In the DDDR and DDIR modes, pacing occurs at the sensor-indicated rate. See “Details about Rate Responsive Pacing” on page 171.

DDDR and DDD modes

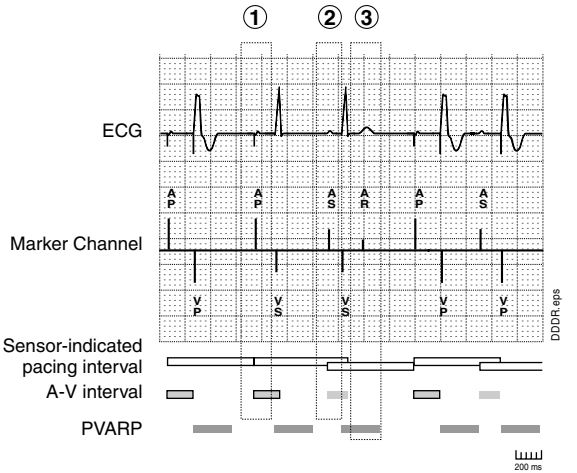
DDDR and DDD are atrial tracking pacing modes. Atrial tracking means that when the device senses an intrinsic atrial event, it schedules a ventricular pace in response. The delay between the sensed atrial event and the corresponding ventricular pace is the programmed Sensed AV interval.

If the current pacing interval ends before the device senses an atrial event, the device paces the atrium and then schedules a ventricular pace after the Paced AV interval.

If a ventricular sensed event occurs during the Sensed AV or the Paced AV interval, ventricular pacing is inhibited.

Note: A sensed atrial event that occurs during the Post-Ventricular Atrial Refractory Period (PVARP) is classified as refractory, does not inhibit atrial pacing, and is not tracked (see Figure 8-1).

Figure 8-1. Example of dual chamber pacing: DDDR mode



1 Atrial paced event starts a Paced AV interval.

2 Atrial sensed event starts a Sensed AV interval.

3 Atrial event that is sensed during PVARP is not tracked.

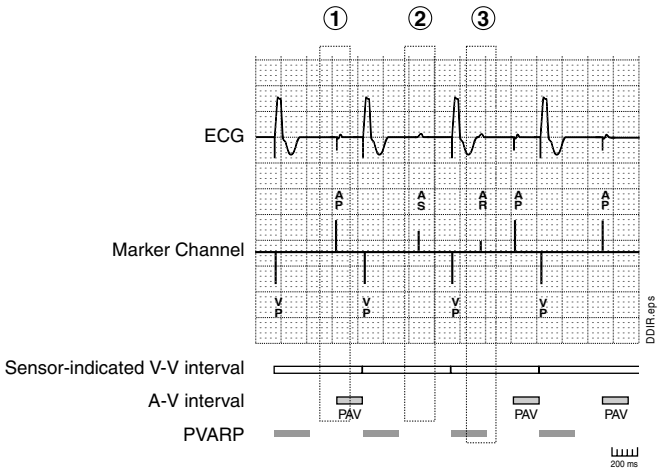
DDIR and DDI modes

In the DDIR and DDI modes, sensed atrial events are not tracked. When an atrial event is sensed, atrial pacing is inhibited, but a Sensed AV is not started. Instead, ventricular pacing is delivered at the current pacing rate (for example, at the lower rate or sensor-indicated rate).

If the current pacing interval ends before the device senses an atrial event, the device paces the atrium and then schedules a ventricular pace after the Paced AV interval. If a ventricular sensed event occurs during the Paced AV interval, ventricular pacing is inhibited.

Note: A sensed atrial event that occurs during the Post-Ventricular Atrial Refractory Period (PVARP) is classified as refractory and does not inhibit atrial pacing (see Figure 8-2).

Figure 8-2. Example of dual chamber pacing: DDIR mode



1 Atrial paced event starts a Paced AV interval.

2 Atrial sensed event inhibits the scheduled atrial pace but does not start a Sensed AV interval (is not tracked).

3 Atrial event that is sensed during PVARP does not inhibit the scheduled atrial pace.

Paced AV interval

The programmable Paced AV interval is the time between a paced atrial event and the following paced ventricular event. The ventricle is paced at the end of the Paced AV interval unless a ventricular event is sensed.

Note: The Paced AV interval is programmable only for dual chamber pacing modes.

The programmed duration for the Paced AV interval may change, depending on how the following parameters are programmed:

- Rate Adaptive AV changes the Paced AV interval as the overall pacing rate changes.
- Non-Competitive Atrial Pacing may shorten the Paced AV interval while maintaining a stable ventricular rate.
- Ventricular Safety Pacing may shorten the Paced AV interval.

Sensed AV interval

The Sensed AV interval is the time between a sensed atrial event and the following paced ventricular event. The ventricle is paced at the end of the Sensed AV interval unless a ventricular event is sensed.

Note: The Sensed AV interval setting is programmable only for DDDR and DDD pacing modes.

The programmed duration for the Sensed AV interval may change depending on either of the following conditions:

- Wenckebach operation, which extends the Sensed AV while tracking a fast intrinsic atrial rate
- Rate Adaptive AV, which changes the Sensed AV interval as the overall atrial rate changes

Post-Ventricular Atrial Refractory Period

The Post-Ventricular Atrial Refractory Period (PVARP) follows a paced, sensed, or refractory sensed ventricular event. An atrial event sensed during this interval is classified as refractory and does not inhibit a scheduled atrial pace or start a Sensed AV interval. The PVARP setting is only programmable for dual chamber pacing modes (except DOO mode).

- In the DDDR and DDD modes, the PVARP setting prevents the sensing of retrograde P-waves that could initiate a pacemaker mediated tachycardia.
- In the DDDR and DDD modes, the PVARP setting prevents the inhibition of atrial pacing based on sensed retrograde P-waves. PVARP should be programmed to a value longer than the VA interval (retrograde) conduction time.

How PVARP interacts with other features – The PVARP setting

- does not affect PR Logic criteria
- may be extended by the PVC Response feature or the PMT Intervention feature

Using the Varied setting – If the PVARP parameter is set to Varied, the duration of the PVARP is based on the current pacing rate. As the pacing rate increases, the PVARP becomes shorter. The Varied setting provides different uses depending on the programmed pacing mode:

- In the DDDR mode, the sensor-varied PVARP setting provides
  - enhanced protection against PMT at lower rates by providing longer PVARPs at low sensor-indicated rates
  - tracking of higher atrial rates (providing a higher 2:1 block rate) by shortening the PVARP at high sensor-indicated rates

  In the DDDR mode, the sensor-varied PVARP ranges from the minimum PVARP (PVAB value) at high rates to a maximum of 400 ms at low rates.
- In the DDIR and DDI modes, the sensor-varied PVARP setting provides
  - improved AV synchrony by preventing inhibition of atrial pacing by an atrial sense early in the VA interval
  - reduced likelihood of competitive atrial pacing at high sensor-indicated rates and when the pacing rate increases because of Ventricular Rate Stabilization

  In DDIR and DDI modes, the sensor-varied PVARP is limited only by the PVAB value.

Within the minimum and maximum boundaries for any dual chamber mode, the PVARP is automatically adjusted to maintain 300 ms between the end of PVARP and the next scheduled atrial pace.

Post-Ventricular Atrial Blanking Period

The Post-Ventricular Atrial Blanking (PVAB) period is a programmable interval during which sensed atrial events are ignored by the bradycardia pacing features. However, the atrial events sensed during PVAB are still used by the PR Logic Criteria.

Interactions with other features – Atrial events falling within the PVAB do not affect Rate Adaptive AV, NCAP, PVC Response, or PMT Intervention.[1]

When Sensor-Varied PVARP is enabled, the programmable PVAB value acts as the minimum PVARP value.

[1] PVAB does not affect Mode Switch.

Programming considerations for atrial rates

In DDDR and DDD modes, the fastest atrial rate the device can track is determined by the sum of the Sensed AV and the Post-Ventricular Atrial Refractory Period. This is referred to as the Total Atrial Refractory Period (TARP).

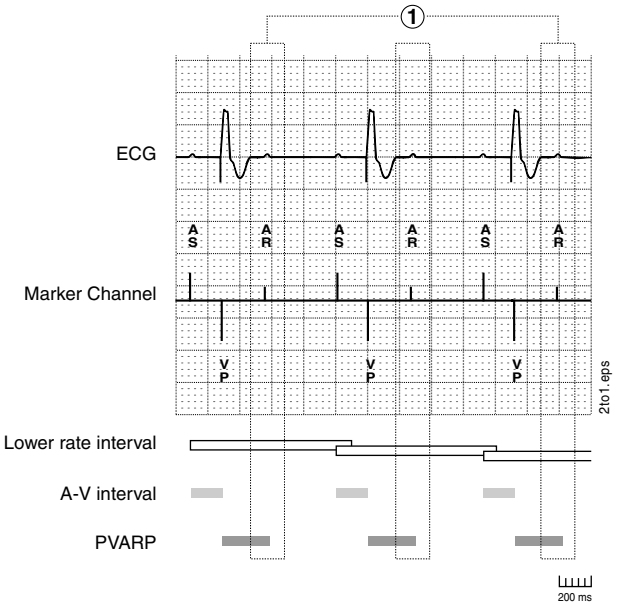
Device behavior at high atrial rates in these modes is determined by the relationship between the TARP and the Upper Tracking Rate interval and/or Upper Sensor Rate interval. In the DDDR mode, the Upper Sensor Rate interval also must be considered.

Note: The upper sensor rate also applies to DDD mode with Mode Switch on.

2:1 Block Rate – If the intrinsic atrial interval is shorter than the TARP, some atrial events occur during the PVARP. These refractory events are not tracked and do not start a Sensed AV interval. At the rate where this first occurs, ventricular tracking occurs only on alternate beats resulting in 2:1 block (see Figure 8-3).

Because only half of the atrial events are tracked, the ventricular rate drops significantly during 2:1 block.

Figure 8-3. Example of the atrial rate exceeding 2:1 block rate



1 One of every two atrial events occurs during PVARP and is not tracked.

You can cause 2:1 block to occur at a higher rate by programming PVARP to Varied, which shortens PVARP, or by turning Rate Adaptive AV on. Both these features shorten the TARP and raise the 2:1 block rate.

Rate responsive pacing in the DDDR mode and the Ventricular Rate Stabilization operation can prevent a precipitous rate drop at the 2:1 block point.

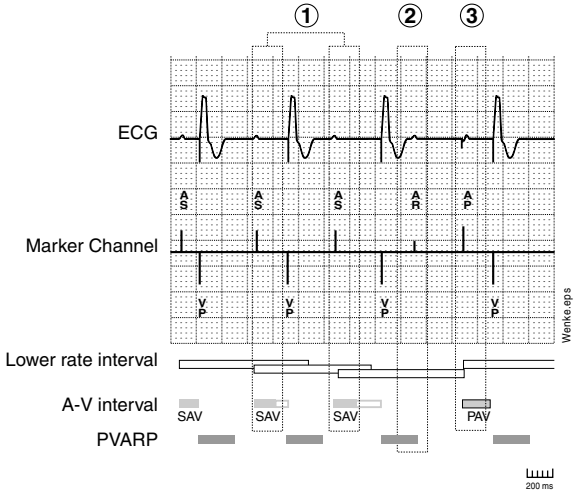
Notes: When the 2:1 block rate is less than the Upper Tracking Rate, the Upper Tracking Rate cannot be achieved. In the DDDR mode, atrial competition may occur if Upper Sensor Rate exceeds the 2:1 block rate.

Wenckebach operation – If the 2:1 block rate is higher than the programmed upper tracking rate, Wenckebach operation may occur. When the intrinsic atrial rate exceeds the upper tracking rate, the device cannot pace the ventricle after the SAV because this would cause the pacing rate to be faster than the upper tracking rate.

In order to maintain the upper tracking rate, Sensed AV extends until the upper tracking rate interval expires. Subsequent Sensed AV intervals require greater extension, until an atrial event falls within the PVARP and is not tracked, as shown in Figure 8-4.

In the DDDR and DDD modes, the normal result is a ratio between atrial and ventricular events (3:2, 4:3, and so forth).

Figure 8-4. Atrial events in PVARP are not tracked during Wenckebach



1 Sensed AV intervals extend so that ventricular paces will not violate Upper Tracking Rate.

2 Atrial event occurs during PVARP and is not tracked.

3 Lower Rate interval expires and the device paces the atrium.

The Wenckebach rate can be smoothed by sensor-driven ventricular pacing (in the DDDR mode) or by using VRS to minimize the rate variation. See “Details about Ventricular Rate Stabilization” on page 178.

Single chamber pacing

Single chamber pacing modes are used to pace either the atrium or the ventricle. In addition to the basic pacing parameters defined on page 148, two programmable parameters are available specifically for single chamber pacing modes.

See details about single chamber pacing on page 165.

Parameters

* Medtronic nominal setting

Single Chamber Hysteresis (bpm, min^{-1}) – enables tracking of intrinsic heart rate below programmed Lower Rate to prevent pacing during extended periods of inactivity, such as when a patient is sleeping.[a]	Off*, 30, 40, 50, 60, 70, 80 Modes: AAI, VVI
ARP (ms) – Atrial Refractory Period, which prevents atrial inhibition due to sensed far-field R-waves or noise.	150, 160, . . ., 310*, 320, 330, . . ., 500 Modes: AAIR, AAI

[a] See “Enhancing pacing for optimal cardiac output” on page 167.

Considerations

Review these programming considerations before programming single chamber pacing parameters.

Warning: Do not use the AAIR or AAI mode in patients with impaired AV nodal conduction because paced atrial events may not trigger intrinsic ventricular events.

Ventricular parameters – Some ventricular parameters are used even when using atrial pacing modes. For example, ventricular sensitivity is used even when the pacing mode is AAIR or AAI because ventricular events are used to detect tachyarrhythmias.

Single-chamber atrial pacing and tachycardia detection – In the AAIR and AAI modes, atrial timing is not based on ventricular events. Thus, if there is a loss of A-V synchrony, atrial pacing pulses can affect detection accuracy by

- causing crosstalk[1]
- masking arrhythmic ventricular events with cross-chamber blanking

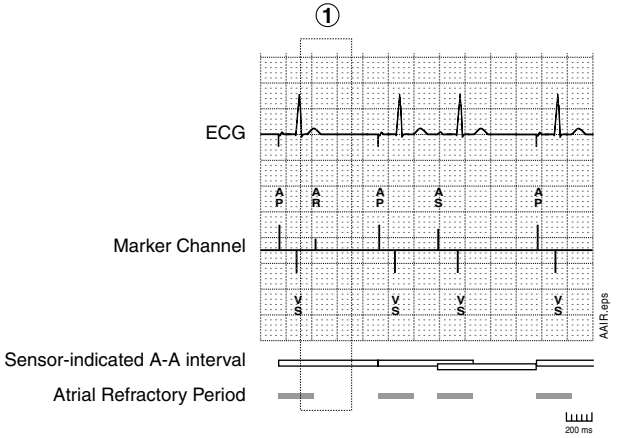
Note: If cross-chamber blanking affects the detection of ventricular events, then the Stability Criterion is also affected. For information about the Stability criterion, see “Enhancing VT detection with the Stability criterion” on page 97.

Details about single chamber pacing

In the AAI and AAIR modes, the atrium is paced if no intrinsic events are sensed. Pacing occurs at the programmed lower rate in the AAI mode and the sensor-indicated rate in the AAIR mode (see Figure 8-5).

Note: During single chamber atrial pacing modes, the device continues sensing ventricular events for tachyarrhythmia detection purposes.

Figure 8-5. Example of single-chamber atrial pacing: AAIR Mode



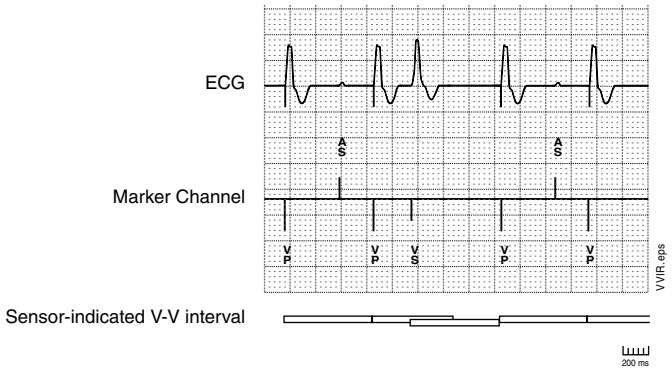
1 An atrial event during the Atrial Refractory Period does not restart the A-A pacing interval.

[1] Crosstalk is the sensing of a pacing stimulus delivered in the opposite chamber.

In the VVIR and VVI modes, the ventricle is paced if no intrinsic events are sensed. Pacing occurs at the programmed lower rate in the VVI mode and at the sensor-indicated rate in VVIR mode (see Figure 8-6).

Note: Atrial sensing and PR Logic criteria operate during single-chamber ventricular pacing.

Figure 8-6. Example of single-chamber ventricular pacing: VVIR mode



Atrial Refractory Period

The Atrial Refractory Period setting is only programmable for the AAI and AAIR single chamber pacing modes.

The Atrial Refractory Period (ARP) prevents the inhibition of atrial pacing due to sensed far-field R-waves or noise and occurs after paced and non-refractory sensed atrial events in the AAIR and AAI modes only.

Enhancing pacing for optimal cardiac output

Several pacing features can be used to adjust the pacing rate to maximize cardiac output during fluctuations in the patient's intrinsic heart rate and level of physical activity.

These features are available based on the selected pacing mode.

See details about these features:

- Rate Responsive Pacing, page 171
- Rate Adaptive AV (RAAV), page 175
- Single Chamber Hysteresis, page 177
- Ventricular Rate Stabilization (VRS), page 178

Parameters

* Medtronic nominal setting

Rate Responsive Pacing – varies the pacing rate in response to a patient's physical activity.	Modes: DDDR, DDD,[a] DDIR, AAIR, VVIR
Rate Response – level of rate response; higher numbers indicate a more aggressive increase in rate for a given level of sensed physical activity.	1, 2, . . ., 7*, . . ., 10
Activity Threshold – minimum physical activity level detected.	Low, Medium Low*, Medium High, High
Activity Acceleration (sec.) – acceleration time for increasing the pacing rate, *measured in seconds*.	15, 30*, 60
Activity Deceleration (min.) – deceleration time for decreasing the pacing rate, *measured in minutes*.	Exercise, 2.5, 5*, 10
Rate Adaptive AV – shortens the AV intervals at high atrial rates.	Modes: DDDR, DDD, DDIR, DDI[b]
Enable	On, Off*
Start Rate (bpm, min^{-1}) – sensed rate value that starts the Rate Adaptive AV operation.	50, 55, 60*, . . ., 145

(continued)	* Medtronic nominal setting
Stop Rate (bpm, min^{-1}) – sensed rate value that stops the Rate Adaptive AV operation.	55, 60, . . ., 120*, . . ., 150
Minimum PAV (ms) – shortest allowable Paced AV interval; used at or above the Stop Rate.	30, 40, . . ., 140*, . . ., 350
Minimum Sensed AV (ms) – shortest allowable Sensed AV interval; used at or above the Stop Rate.	30, 40, . . ., 110*, . . ., 350
Single Chamber Hysteresis (bpm, min^{-1}) – enables tracking of patient's intrinsic rhythm below programmed Lower Rate to prevent pacing during extended periods of inactivity, such as when a patient is sleeping.	Off*, 30, 40, 50, 60, 70, 80 Modes: AAI, VVI
Ventricular Rate Stabilization – eliminates the long pause that typically follows a premature ventricular contraction.	Modes: DDDR, DDD, DDIR, DDI, VVIR, VVI
Enable	On, Off*
Interval Increment (ms) – value added to the previous V-V interval to determine the current VRS interval.	50, 60, . . ., 150*, . . ., 400
Minimum Interval (ms) – shortest allowable interval.	500*, 550, . . ., 900

[a] When Mode Switch is on.

[b] When VRS is on.

Considerations

Review these programming considerations before programming Single Chamber Hysteresis, Rate Responsive Pacing, or Rate Adaptive AV.

Verify Adequate Cardiac Support – Before programming Single Chamber Hysteresis, verify that the selected hysteresis rate is adequate to support the patient's cardiac condition.

Rate Responsive Pacing

- When pacing in DDD mode, the Rate Responsive Pacing parameters apply only if Mode Switch is programmed on.
- If the patient has minimal rate response during exercise, you may need to program the Activity Threshold to a lower setting.
- The device may pace at higher rates in response to strong environmental vibrations. Such rates are limited by the Upper Sensor Rate. To control this response, program the Upper Sensor Rate to a value that is appropriate to the patient's condition and/or adjust the Activity Threshold to a less sensitive setting.
- The sensor-indicated rate does not change during
  - automatic tachyarrhythmia therapies
  - system tests
  - EP study inductions and manual therapies
  - a patient alert alarm

Rate Adaptive AV

- For patients with normal A-V conduction, configure Rate Adaptive AV parameters to allow intrinsic A-V conduction at rates below 90 ppm (min^{-1}).
- In DDD mode, Rate Adaptive AV adjusts only the PAV interval during Mode Switch (see page 182) and VRS (see page 178) operations.
- Rate Adaptive AV is suspended during automatic therapies, system tests, and EP Study operations. Rate Adaptive AV operation resumes once these functions are complete.

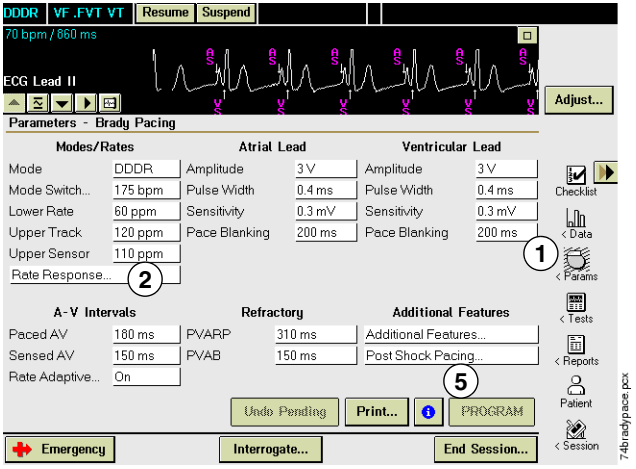
Restrictions

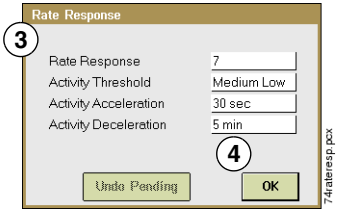
Review the following information before programming Single Chamber Hysteresis or Ventricular Rate Stabilization (VRS).

Compatibility – Single Chamber Hysteresis and Ventricular Rate Stabilization cannot be programmed on at the same time.

For a complete list of restrictions, see “Parameter interlocks” on page 386.

How to program Rate Response





1. Select Params icon > Brady Pacing.
2. Select [Rate Response...].
3. Set Rate Response, Activity Threshold, Activity Acceleration, and Activity Deceleration to desired values.
4. Select [OK].
5. Select [PROGRAM].

Details about Rate Responsive Pacing

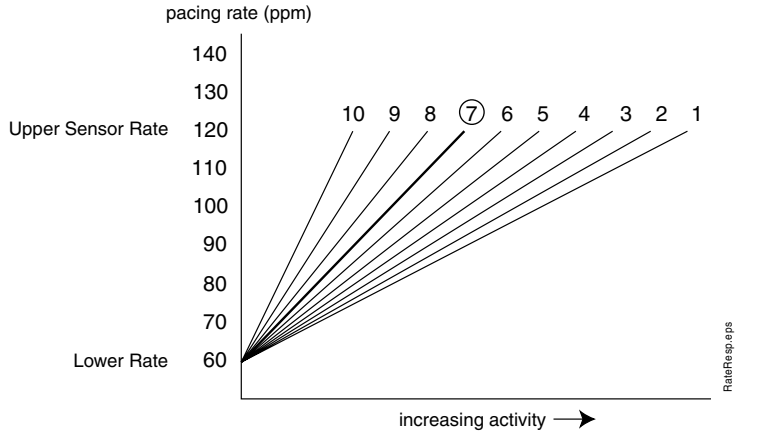
Rate Responsive Pacing can be used to vary the pacing rate in response to detected physical activity. The device accelerometer provides sensed activity information by detecting body movement.

When a rate responsive pacing mode is enabled, pacing is delivered at a sensor-indicated rate. The sensor-indicated rate is determined by the sensed activity and the Rate Response parameter setting and can range between the programmed lower rate and the upper sensor rate.

The Rate Response parameter is set to a number between one and ten. The larger the setting number, the more aggressive the indicated pacing rate for a given level of detected activity.[1]

- If the sensor-indicated rate is greater than the current pacing rate, then the pacing rate is accelerated toward the sensor-indicated rate. The speed of this increase is determined by the Activity Acceleration parameter setting.
- If the sensor-indicated rate decreases, the pacing rate decelerates to the sensor-indicated rate. The rate of deceleration is determined by the programmed Activity Deceleration rate.

Figure 8-7. Rate Response setting depends on the programmed Upper Sensor and Lower Rate (nominal setting = 7)



[1] The actual beat-to-beat change is also influenced by the Rate Response Activity Acceleration setting and the sensed level of activity.

Activity Acceleration and Deceleration settings – Activity Acceleration and Deceleration settings determine the amount of time required to reach 90% of the new pacing interval. Figure 8-8 illustrates the acceleration curves at the onset of strenuous exercise and Figure 8-9 illustrates the deceleration curves when exercise is abruptly ended.

Figure 8-8. Rate Response Activity Acceleration curves influence how quickly the device responds to increased activity

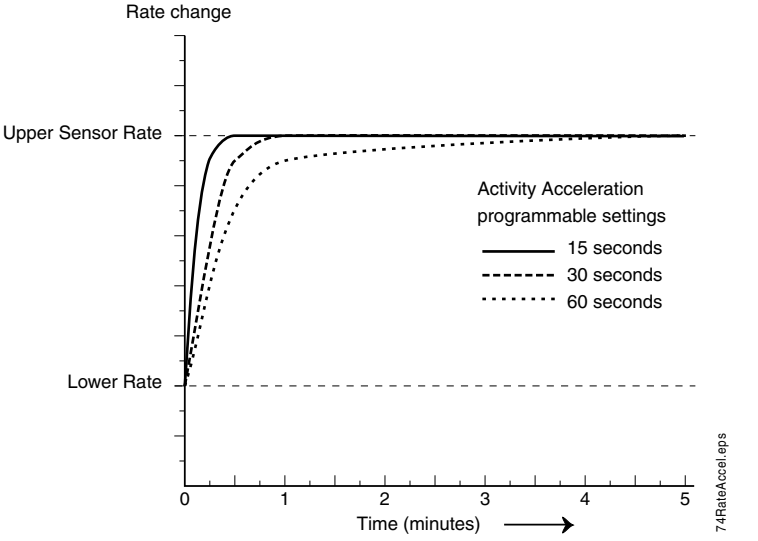
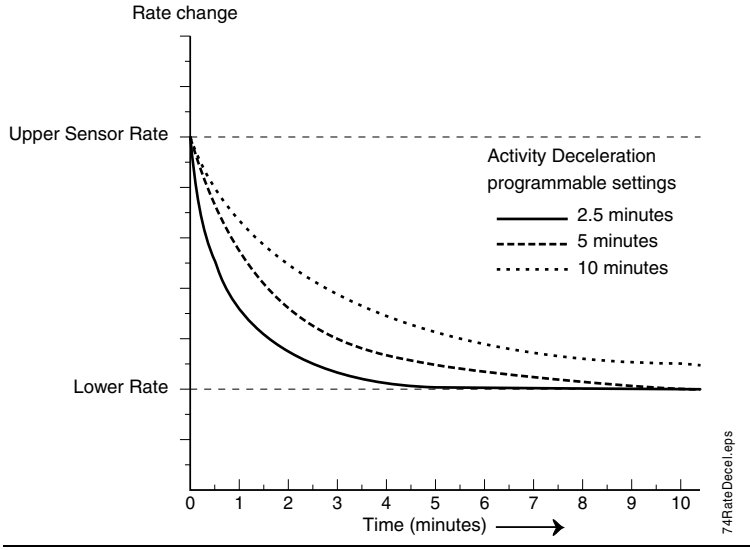
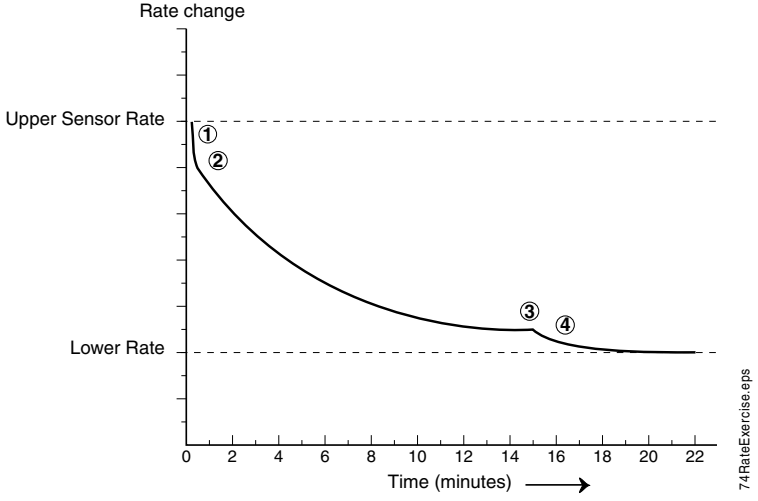


Figure 8-9. Rate Response Activity deceleration curves influence how quickly the device responds to decreased activity



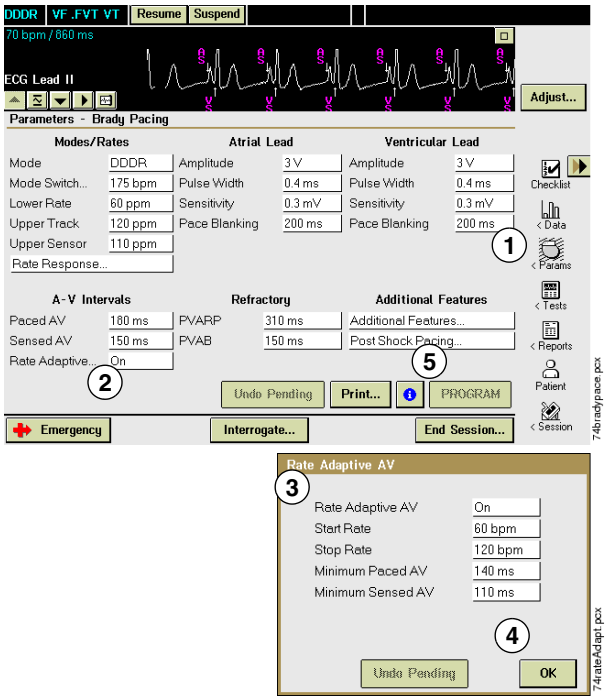
Exercise Deceleration option – If the Activity Deceleration parameter is set to Exercise, the device extends the rate-slowing period following an exercise episode, providing up to 20 minutes of rate deceleration, as illustrated in Figure 8-10.

Figure 8-10. Exercise Deceleration option



1 5 minute deceleration.
2 20 minute deceleration begins.
3 20 minute deceleration ends.
4 5 minute deceleration curve.

How to program Rate Adaptive AV



1. Select Params icon > Brady Pacing.
2. Select [Rate Adaptive...].
3. Set the Rate Adaptive AV parameter to On and select values for Start Rate, Stop Rate, Minimum Paced AV, and Minimum Sensed AV.
4. Select [OK].
5. Select [PROGRAM].

Details about Rate Adaptive AV

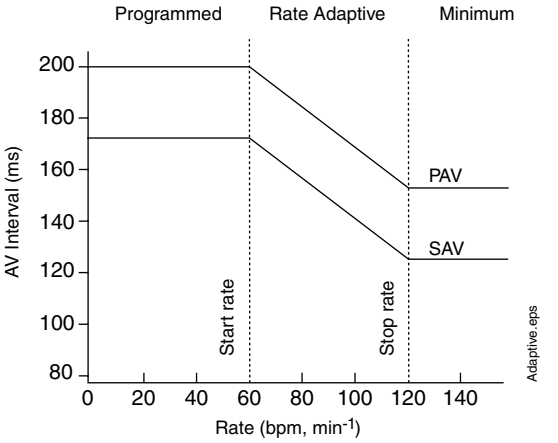
Rate Adaptive AV can be used to mimic the natural AV conduction time in response to heart rate. Normally, as the heart rate increases, the AV conduction time decreases, and as the heart rate decreases, the AV conduction time increases.

Rate Adaptive AV shortens the Sensed AV interval in response to the V-V Median[1] and the Paced AV interval in response to the current pacing rate (for example, the lower rate or sensor-indicated rate).

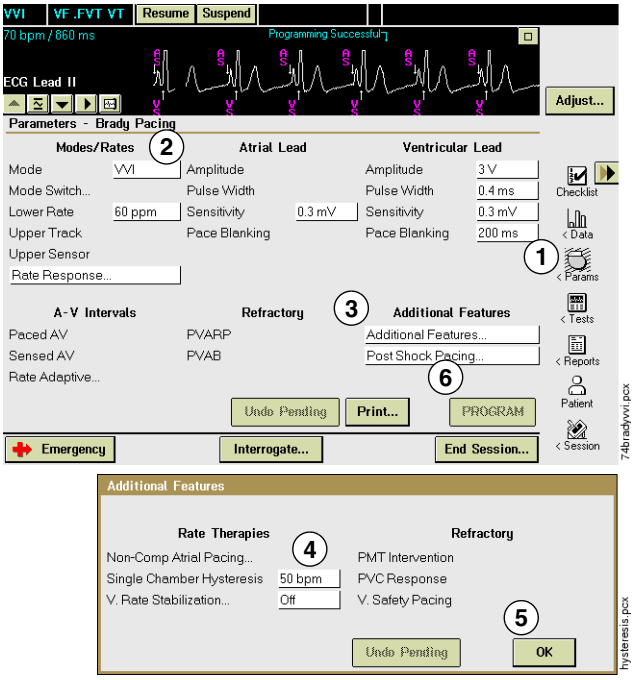
Figure 8-11 shows how Rate Adaptive AV parameters interact to shorten the AV intervals in response to higher rates.

[1] The median of the last 12 V-V intervals.

Figure 8-11. Rate Adaptive AV operation in DDDR mode



How to program Single Chamber Hysteresis



1. Select Params icon > Brady Pacing.
2. Program pacing mode to VVI or AAI.
3. Select [Additional Features ...].
4. Set the Single Chamber Hysteresis parameter to the desired value.
5. Select [OK].
6. Select [PROGRAM].

Details about Single Chamber Hysteresis

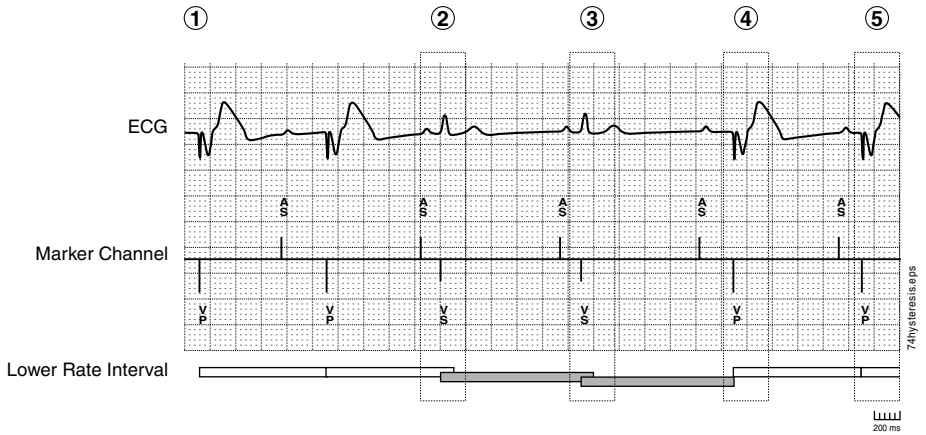
Single Chamber Hysteresis allows intrinsic heart rates to fall below the programmed lower rate during extended periods of patient inactivity, such as when the patient is sleeping. Hysteresis is programmed to a rate below the lower rate in order to support slow but appropriate intrinsic rhythms.

Single Chamber Hysteresis temporarily provides a new lower rate when the intrinsic rate is below the programmed lower rate. The hysteresis rate is applied if it is slower than the intrinsic rate. If the intrinsic rate drops below the hysteresis rate, then pacing is reestablished at the programmed lower rate.

Note: The difference between the Hysteresis Rate and the programmed Lower Rate is typically not greater than 30 ppm.

If a tachyarrhythmia episode is detected, hysteresis is suspended. Hysteresis remains suspended until the episode terminates.

Figure 8-12. Single Chamber Hysteresis supports a slower rate than the programmed lower rate



1 The devices paces in VVI mode at the programmed Lower Rate.

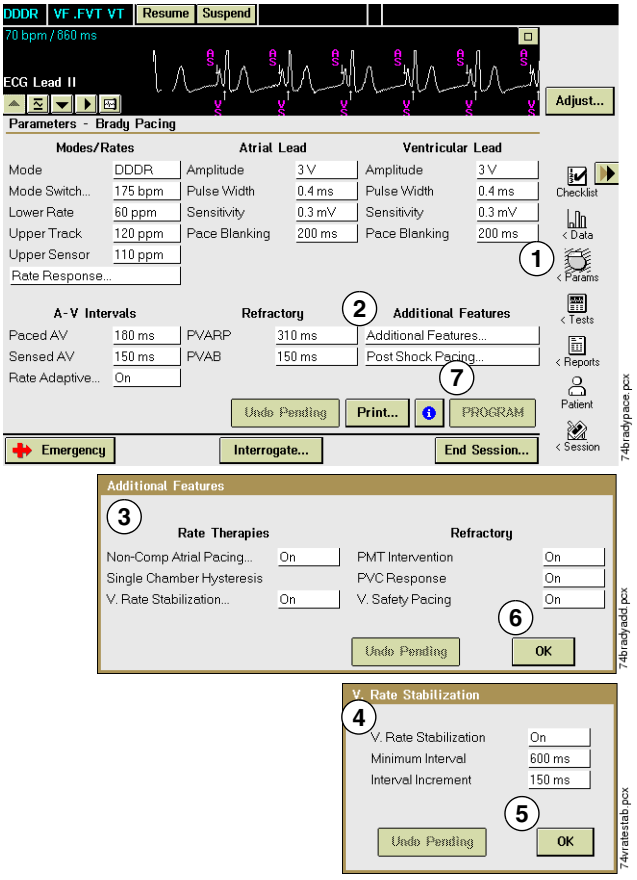
2 After a ventricular sensed event, the device applies the hysteresis interval (shaded bar).

3 A sensed event occurs before the hysteresis interval expires, so hysteresis operation continues.

4 The hysteresis interval expires, and the device paces the ventricle and reapplies the lower rate interval.

5 The ventricle is paced at the lower rate.

How to program Ventricular Rate Stabilization



1. Select Params icon > Brady Pacing.
2. Select [Additional Features …].
3. Select the V. Rate Stabilization... [On/Off] button.
4. Set the V. Rate Stabilization parameter to On and set Minimum Interval and Interval Increment to desired values.
5. Select [OK].
6. Select [OK] from the Additional Features... screen.
7. Select [PROGRAM].

Details about Ventricular Rate Stabilization

Ventricular Rate Stabilization (VRS) is designed to eliminate the long pause that typically follows a premature ventricular contraction (PVC). These short-long interval sequences have been clinically observed to precede the onset of some spontaneous ventricular tachyarrhythmias.

When VRS is enabled, it acts as a constant rate-smoothing algorithm. On each ventricular event, the device calculates the VRS interval as the sum of the previous ventricular interval plus the programmed interval increment value (or the VRS Minimum Interval, if it is larger than this sum).

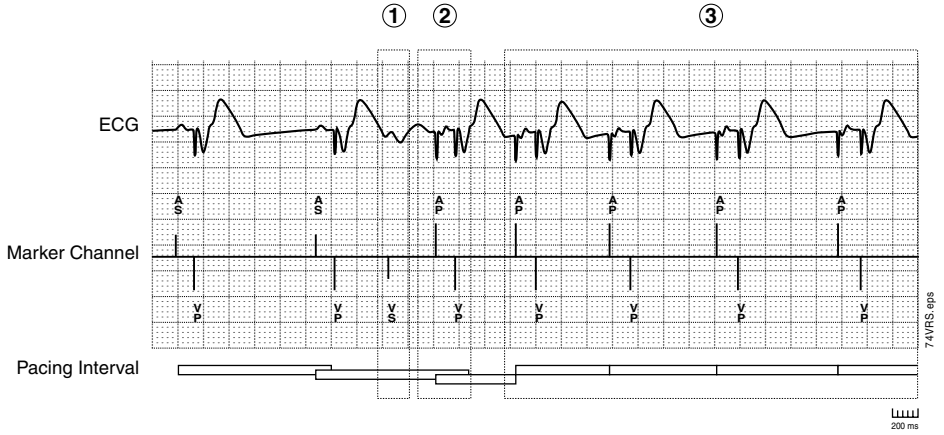
If the VRS interval is shorter than the current pacing interval and no intrinsic ventricular event occurs, the device delivers a ventricular pace at the end of the VRS interval. The VRS interval is then recalculated based on the last ventricular interval. The VRS interval lengthens, from beat to beat, by a value equal to the programmable VRS Interval Increment.

Once the rate generated by VRS operation slows to the intrinsic, sensor-indicated, or lower rate, the device returns to normal pacing operation.

Note: In dual-chamber pacing modes, VRS automatically shortens the atrial pacing interval so the ventricular pacing pulse is delivered at the required VRS escape interval.

Figure 8-13 shows an example of VRS smoothing the ventricular rate after a PVC.

Figure 8-13. Example of Ventricular Rate Stabilization



1 A PVC occurs, causing a short V-V interval.

2 VRS paces the ventricle at the previous V-V interval plus the programmed Interval Increment (and schedules the atrial pace early, to maintain AV synchrony).

3 With each successive VRS pace, the pacing interval increases by the programmed Interval Increment.

Adjusting the pacing rate with Mode Switch

Use Mode Switch to avoid tracking sensed atrial events during atrial arrhythmias. If an atrial tachyarrhythmia is detected and Mode Switch is on, the device temporarily switches the pacing mode to DDIR until the arrhythmia terminates. Mode switch is available when the selected pacing mode is either DDD or DDDR.

See “Details about Mode Switch” on page 182.

Parameters

* Medtronic nominal setting

Mode Switch – automatically switches the pacing mode to DDIR during an atrial tachyarrhythmia.	Modes: DDDR, DDD
Enable	On, Off*
A. Detect Rate (bpm, min^{-1}) – rate threshold which indicates atrial tachyarrhythmia.	120, 125, . . ., 175*

Considerations

Review the following information before programming Mode Switch.

△ **Caution:** Mode Switch is not recommended for patients with chronic, refractory atrial tachyarrhythmias.

Interactions with other Pacing Features – The Mode Switch feature temporarily suspends NCAP, PMT Intervention, and PVC Response features.

During Mode Switch episodes, the PVARP Varied setting is used temporarily.

After high voltage therapy and T-Shock induction – Mode Switch remains active during charging but is suspended when charging ends. Mode Switch remains suspended until the high voltage shock is delivered or aborted. After the high voltage shock is delivered or aborted, Mode Switch remains active or ends:

- If the current pacing mode is DDIR or DDI, the Mode Switch episode remains active after therapy, pacing in the DDIR mode.
- If the current pacing mode is *not* DDIR or DDI, the Mode Switch episode ends, and the device resumes atrial tachyarrhythmia detection.

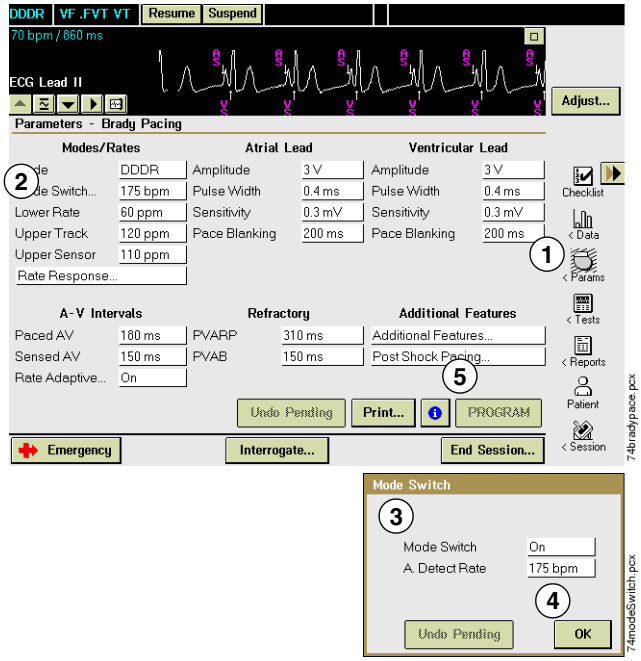
After non-high voltage therapies and tests – If Mode Switch is active, the pacing mode automatically changes to DDIR after the delivery of ATP, defibrillation, and cardioversion therapies or tests. The device then resumes normal Mode Switch operation.

Restrictions

Review the following information before programming Mode Switch On.

Upper Sensor Rate – To ensure appropriate atrial tachyarrhythmia detection when Mode Switch is on, the Upper Sensor Rate must be less than or equal to the Upper Tracking Rate.

How to program Mode Switch



1. Select Params icon > Brady Pacing.
2. Select Mode Switch On/Off field from the Brady pacing screen.
3. Set the Mode Switch parameter to On, and set A. Detect Rate to desired value.
4. Select [OK].
5. Select [PROGRAM].

Details about Mode Switch

If Mode Switch detects an atrial tachyarrhythmia, the device switches to a non-atrial tracking pacing mode for the duration of the high atrial rate so that an inappropriate atrial rate does not influence the ventricular pacing rate.

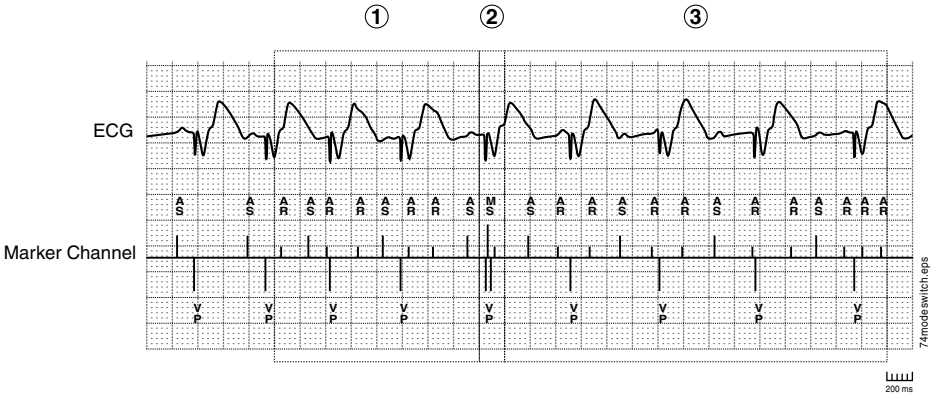
Mode Switch detects an atrial tachyarrhythmia if the A-A median[1] exceeds the programmable Atrial Detect Rate (and satisfies the AF/AT evidence criterion). Termination of the atrial tachyarrhythmia is detected when the atrial rate is less than or equal to the Upper Tracking Rate.

To avoid an abrupt drop in the ventricular rate, the device smoothly reduces the pacing rate from the atrial synchronous rate to the sensor-indicated rate.

[1] The median of the last 12 A-A intervals.

Once the atrial tachyarrhythmia ends, the device returns to the programmed atrial-tracking pacing mode, gradually adjusting the pacing rate toward the lower rate (DDD mode) or the sensor-indicated rate (DDDR mode); see Figure 8-14.

Figure 8-14. When an atrial tachyarrhythmia is detected, Mode Switch changes to non-atrial tracking mode



1 An atrial tachyarrhythmia starts, causing rapid ventricular pacing in response.

2 The atrial tachyarrhythmia is detected, and Mode Switch changes the pacing mode to DDIR.

3 The device gradually changes from the high atrial tracking pacing rate to the slower sensor-indicated rate.

Preventing competitive atrial pacing

Non-Competitive Atrial Pacing (NCAP) is designed to prevent triggering of atrial tachycardias by delaying an atrial pace that is scheduled to fall within the relative atrial refractory period. NCAP may be enabled in the DDDR and DDD mode.

See details about the Non-competitive Atrial Pacing (NCAP) on page 185.

Parameters

* Medtronic nominal setting

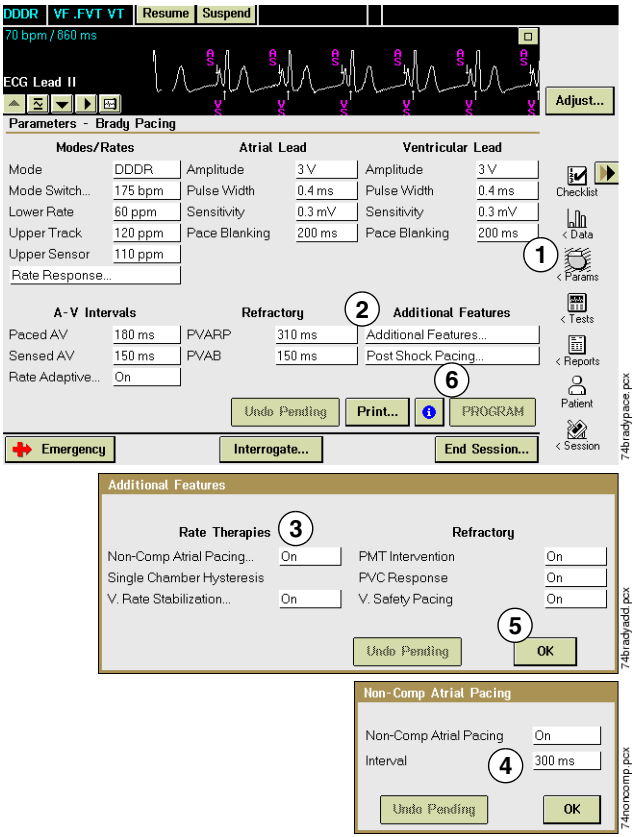
Non-Competitive Atrial Pacing (NCAP) – delays an atrial pace scheduled to fall within the relative atrial refractory period to prevent triggering an atrial tachyarrhythmia.	Modes: DDDR, DDD
Enable	On*, Off
Interval (ms)	200, 250, 300*, 350, 400

Considerations

Review the following information before programming Non-Competitive Atrial Pacing.

Ventricular pacing – When a relatively high lower rate and long PVARP are programmed, NCAP operation may result in ventricular pacing slightly below the lower rate.

How to program Non-Competitive Atrial Pacing



1. Select Params > Brady Pacing.
2. Select [Additional Features...].
3. Set Non-Competitive Atrial Pacing to On.
4. Set the interval and select [OK].
5. Select [OK] from the Additional Features screen.
6. Select [PROGRAM].

Details about Non-Competitive Atrial Pacing

Non-Competitive Atrial Pacing (NCAP) delays an atrial pace scheduled to fall within the relative atrial refractory period to prevent triggering an atrial tachyarrhythmia. Using the NCAP Interval parameter, you can program how long to delay an atrial pace if a refractory atrial event is sensed within the PVARP.[1]

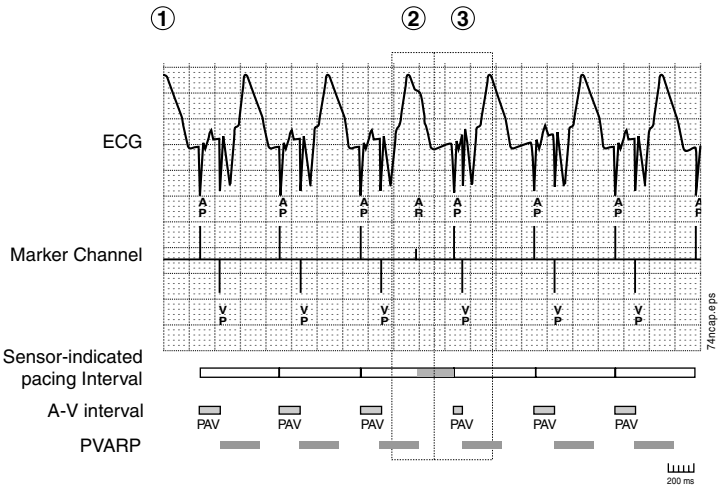
- If an atrial pace is scheduled to occur during the NCAP interval, the atrial pace is delayed until the NCAP interval expires.
- If no atrial pace is scheduled to occur during the NCAP interval, timing is unaffected.

[1] Atrial refractory senses that occur within the programmable PVAB period do not start an NCAP interval (see page 160).

If another atrial refractory sensed event occurs during the NCAP interval, a new NCAP interval begins.

When an atrial pace is delayed by the NCAP feature, the Paced AV interval decreases to maintain a stable ventricular rate. The Paced AV interval will not decrease to less than 30 ms.

Figure 8-15. Non-Competitive Atrial Pacing operation



1 The device is pacing at the Upper Sensor Rate of 120 ppm (min^{-1}).

2 An atrial refractory event occurs, starting an NCAP interval (300 ms in this case).

3 After the NCAP interval expires, the device paces the atrium and then paces the ventricle after a shortened Paced AV interval.

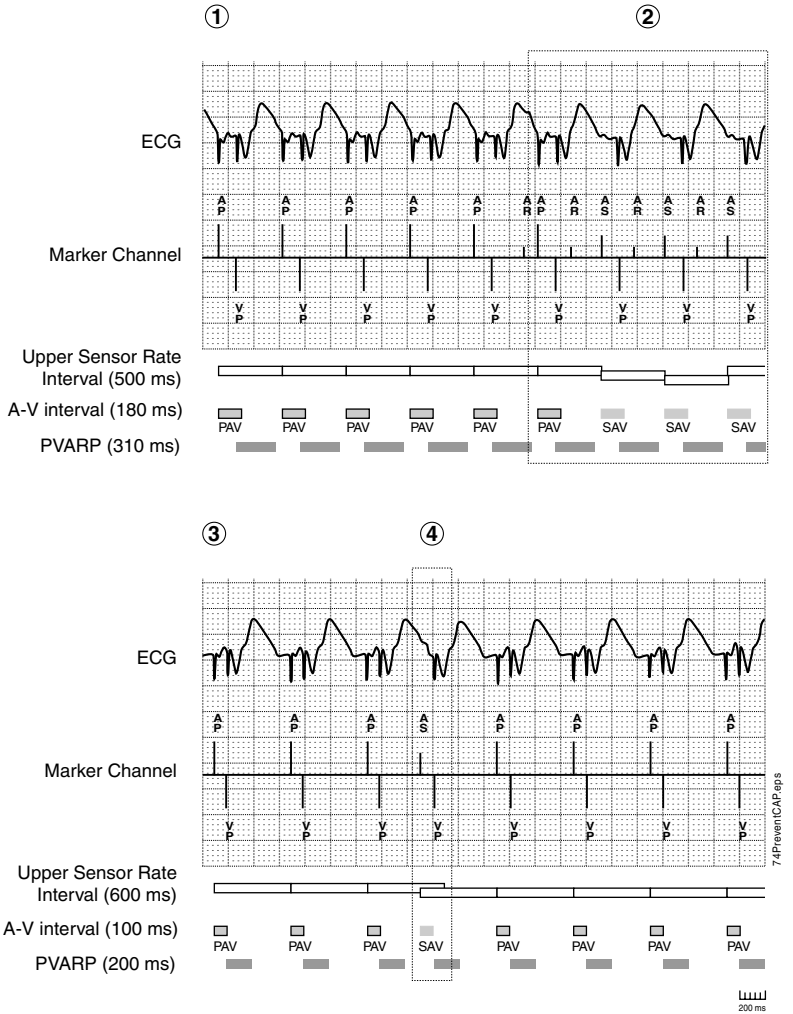
Other methods of preventing competitive atrial pacing

Because the device does not respond to atrial events during an atrial refractory period, an atrial pace may fall immediately after a refractory event and cause competitive atrial pacing.

The bradycardia pacing parameters should be programmed to provide 300 ms between the end of the atrial refractory period and the next scheduled atrial pace.

Figure 8-16 shows such an adjustment in the DDDR mode: Lowering the Upper Sensor Rate, shortening the PAV, and shortening the PVARP provides a 300 ms interval with no atrial pacing after the PVARP.

Figure 8-16. Preventing competitive atrial pacing by reprogramming pacing parameters



1 With pacing occurring at the Upper Sensor Rate of 120 ppm (min^{-1}), A-V intervals = 180 ms, and PVARP = 310 ms, the minimum interval between the end of PVARP and the next atrial pace is 10 ms.

2 An atrial pace is delivered immediately after an atrial refractory event, causing competitive atrial pacing, which triggers an atrial tachyarrhythmia.

3 With pacing occurring at the Upper Sensor Rate of 100 ppm (min^{-1}), A-V intervals = 100 ms, and PVARP = 200 ms, the minimum interval between the end of PVARP and the next atrial pace is 300 ms.

4 An intrinsic atrial event occurs after the shorter PVARP interval and is sensed.

Table 8-3 lists some suggestions for modifying parameters to avoid competitive atrial pacing, depending on the selected pacing mode.

Table 8-3. Preventing competitive atrial pacing by reprogramming

Pacing mode	Pacing parameter	Possible reprogramming
AAIR and AAI	Pacing interval	▪ Reduce Upper Sensor Rate (AAIR only) ▪ Reduce Lower Rate
	Atrial Refractory Period	▪ Reduce ARP
DDDR, DDD, DDIR, and DDI	Pacing escape interval	▪ Reduce Upper Sensor Rate ▪ Reduce Lower Rate ▪ Increase VRS Minimum Interval if VRS is on ▪ Disable VRS
	PAV	▪ Reduce PAV ▪ Enable RAAV ▪ Reduce Minimum PAV if RAAV is on
	PVARP	▪ Reduce PVARP ▪ Set PVARP to Varied ▪ Reduce PVAB if PVARP is Varied ▪ Disable PVC Response

Detecting and preventing pacemaker-mediated tachycardia

A pacemaker-mediated tachycardia (PMT) may occur when retrograde P-waves are sensed and tracked in an atrial tracking mode (due to a loss of AV synchrony). Since premature ventricular contractions (PVCs) are known to initiate PMT, one way to prevent PMT is to detect PVC events and extend the PVARP by enabling PVC Response.

PMT intervention can be used to detect and interrupt PMT automatically.

△ **Caution:** Some PMTs may require intervention such as device reprogramming, drug therapy, or lead evaluation.

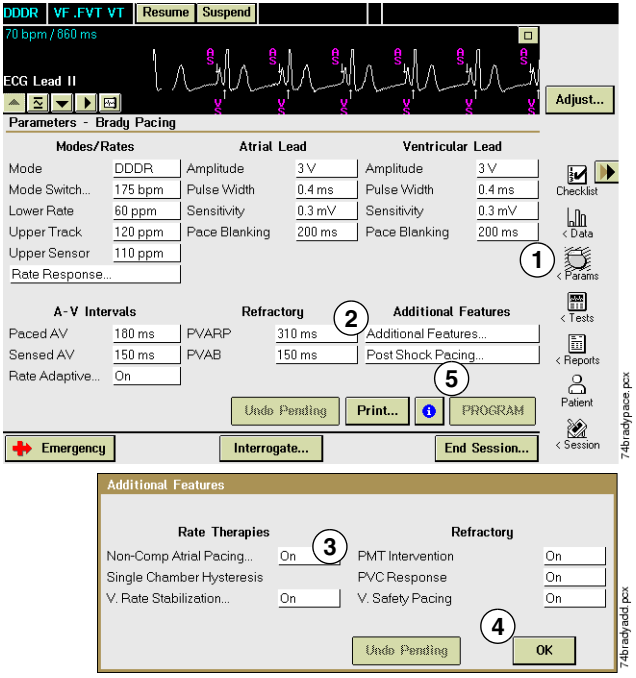
See details about PVC response and PMT intervention on page 190 and on page 191.

Parameters

* Medtronic nominal setting

PVC Response – detects a PVC event and responds by extending the PVARP to 400 ms (if the currently programmed or Sensor-Varied PVARP is less than 400 ms).	Modes: DDDR, DDD, DDIR, DDI
Enable	On, Off*
PMT Intervention – automatically detects and interrupts device atrial tracking for one cycle in response to PMT.	Modes: DDDR, DDD
Enable	On, Off*

How to Program PVC Response and PMT Intervention



1. Select Params icon > Brady Pacing.
2. Select [Additional Features...] from the Brady pacing screen.
3. Set PVC Response to On and PMT Intervention to On.
4. Select [OK].
5. Select [PROGRAM].

Details about PVC Response

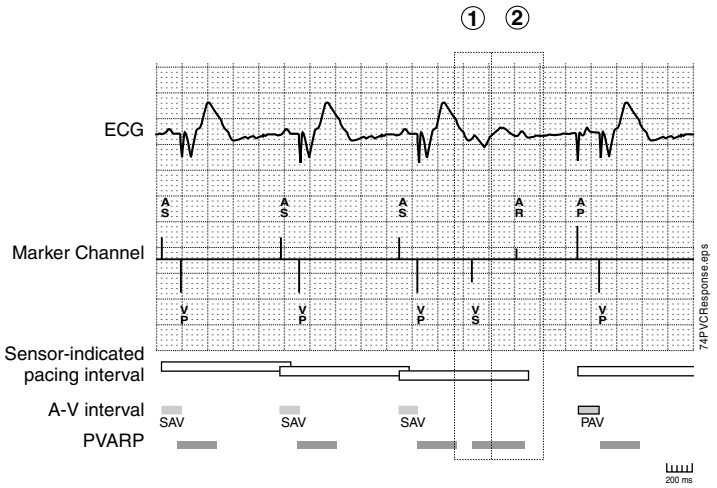
The device defines a PVC as any ventricular sensed event that follows a ventricular event without an intervening atrial event.[1]

When PVC Response is on, a PVC starts an extended PVARP of 400 ms if the current PVARP (either the programmed or Sensor-Varied PVARP value) is less than 400 ms. This extended PVARP causes retrograde P-waves occurring within 400 ms to fall into the refractory period.

PVC Response is suspended during automatic tachyarrhythmia therapies, system tests, EP Study inductions, and manual therapies.

[1] Atrial refractory events falling within the programmable PVAB period are ignored by PVC detection.

Figure 8-17. PVC Response starts an extended PVARP



1 A PVC occurs.

2 The device extends PVARP to 400 ms, and the subsequent atrial event is classified as refractory.

Details about PMT Intervention

The device detects a PMT after sensing eight V-A intervals that

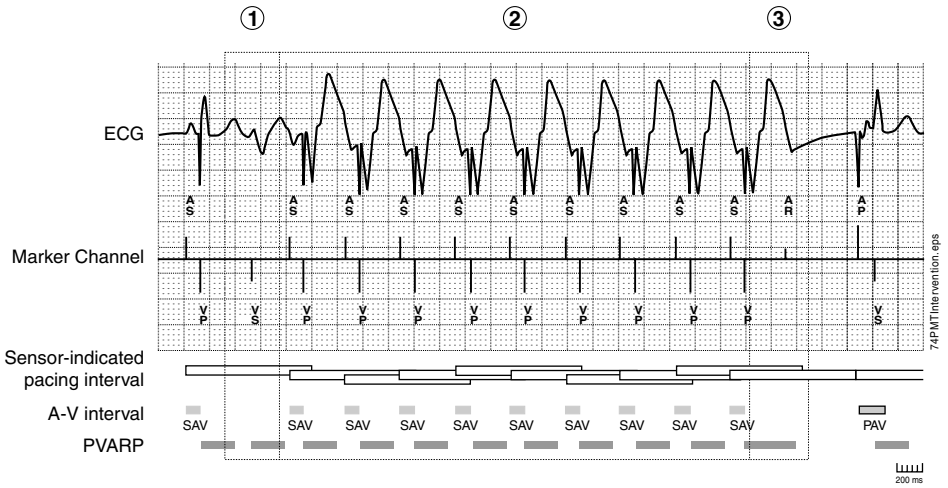
- are less than 400 ms
- start with a ventricular pace
- end with a non-refractory atrial sense

PMT Intervention forces a 400 ms PVARP after the ninth paced ventricular event. This ensures that the next atrial sensed event within 400 ms will occur within the refractory period. Because this refractory event is not tracked to the ventricle for one cycle, the PMT is interrupted.

PMT Intervention is suspended for 90 seconds following an intervention in order to prevent unnecessary intervention in the presence of fast intrinsic atrial rates. PMT Intervention is also suspended during automatic tachyarrhythmia therapies, system tests, EP Study inductions, and manual therapies.

Note: A sinus tachycardia may initiate a PMT intervention, causing a single P-wave to fall in the PVARP where it is not tracked by the device.

Figure 8-18. PMT Intervention extends PVARP



1 A PVC occurs and is conducted from the ventricle into the atria.

2 The device senses the atrial depolarization cased by the retrograde event, and a PMT is triggered.

3 The device detects the PMT after eight VP-AS intervals occur that are shorter than 400 ms. After the ninth ventricular paced event, it extends PVARP to 400 ms for one event. The atrial event is not tracked, and the PMT terminates.

Providing Ventricular Safety Pacing

Ventricular Safety Pacing (VSP) prevents inappropriate inhibition of ventricular pacing due to cross-chamber sensing of atrial paced events. If an atrial paced event is followed by a ventricular sensed event that occurs during the VSP interval, the device delivers a backup ventricular pace.

△ **Caution:** For pacemaker-dependent patients, always program Ventricular Safety Pacing on.

See details about Ventricular Safety Pacing on page 194.

Parameters

* Medtronic nominal setting

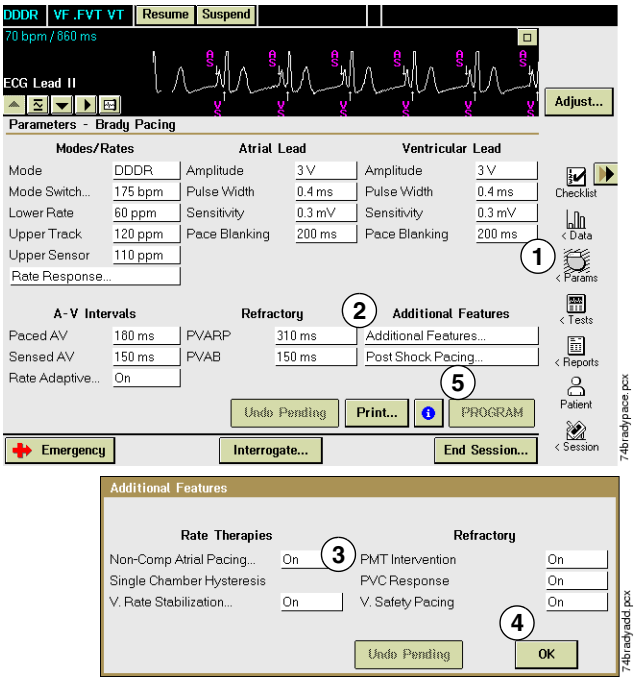
Ventricular Safety Pacing – prevents inappropriate inhibition of ventricular pacing due to ventricular oversensing.	Modes: DDDR, DDD, DDIR, DDI
Enable	On*, Off

Restrictions

Review the following information before programming Ventricular Safety pacing.

Programmable parameters – In order to ensure reliable ventricular tachyarrhythmia detection when Ventricular Safety Pacing is on, the programmable values for Lower Rate, Upper Sensor Rate, and Ventricular Pace Blanking are limited.

How to program Ventricular Safety Pacing



1. Select Params icon > Brady Pacing.
2. Select [Additional Features...] from the Brady pacing screen.
3. Set V. Safety Pacing to On.
4. Select [OK].
5. Select [PROGRAM].

Details about Ventricular Safety Pacing

A Ventricular Safety Pace is delivered if a ventricular event is sensed within the current Ventricular Safety Pace (VSP) interval after an atrial pace.

The VSP interval depends on the current ventricular rate. If the current ventricular rate is

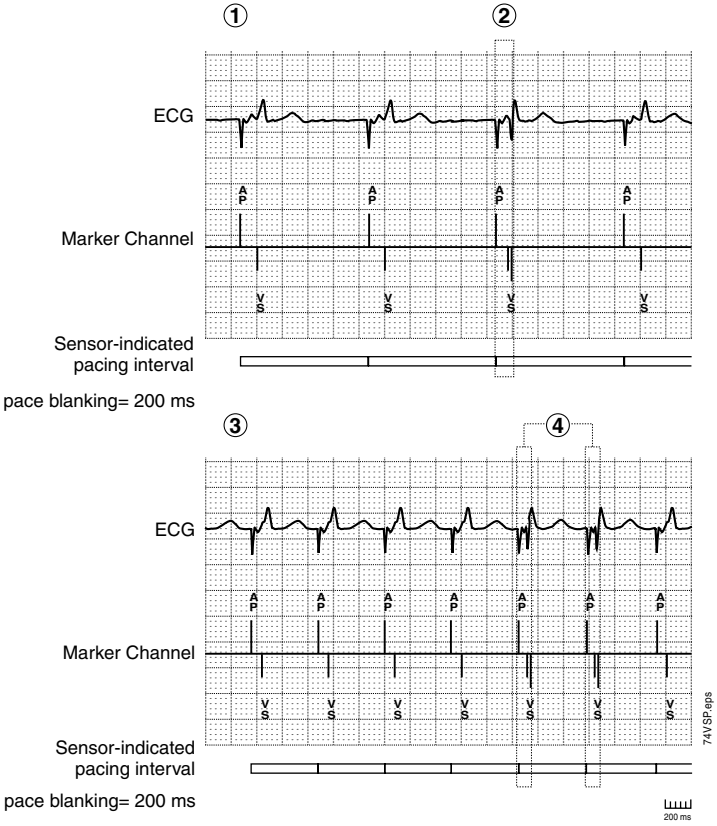
- lower than the VSP switch rate, the VSP interval is 110 ms
- at or above the VSP switch rate, the VSP interval is 70 ms

The programmer automatically calculates the VSP Switch Rate as follows:

$$\text{VSP switch rate} = \frac{60{,}000}{2^{*}\ (\text{V. pace blanking} + 110\ \text{ms})}$$

The delivery timing of Ventricular Safety Pace depends on the length of the Paced AV. The ventricle is paced at the end of the Paced AV or at the end of the current VSP Interval, whichever occurs first.

Figure 8-19. Ventricular Safety Pacing below and above switch rate



1 The pacing rate is 60 ppm (min^{-1}), which is below the VSP switch rate, so the VSP Interval is 110 ms.

2 An atrial pace is followed by a ventricular sense that falls within the VSP interval, so the device delivers a ventricular safety pace synchronized with the sensed event.

3 The pacing rate is 115 ppm (min^{-1}), which is above the VSP switch rate, so the VSP Interval is 70 ms.

4 For two beats, an atrial pace is followed by a ventricular sense that falls within the VSP interval, so the device delivers a ventricular safety pace at the end of the VSP interval.

Providing pacing after high voltage therapies

In order to ensure capture following a high voltage therapy, a separate set of basic pacing parameters is available for pacing support after high voltage therapies.

See “Details about Post Shock Pacing parameters” on page 197.

Parameters

* Medtronic nominal setting

Post Shock Pacing Parameters	Modes: All[a]
Atrial Pulse Width (ms) **–** Duration of atrial pacing pulses.	0.03, 0.06, 0.1, 0.2, . . ., 1.6*
Atrial Pulse Amplitude (V) **–** Voltage of atrial pacing pulses.	0.5, 1, . . ., 4*, 5, 6, 8
Ventricular Pulse Width (ms) **–** Duration of ventricular pacing pulses.	0.03, 0.06, 0.1, 0.2, . . ., 1.6*
Ventricular Pulse Amplitude (V) **–** Voltage of ventricular pacing pulses.	0.5, 1, . . ., 4, 5, 6*, 8

[a] Atrial Pulse Width and Amplitude parameters are not available for VVIR, VVI, or ODO modes.

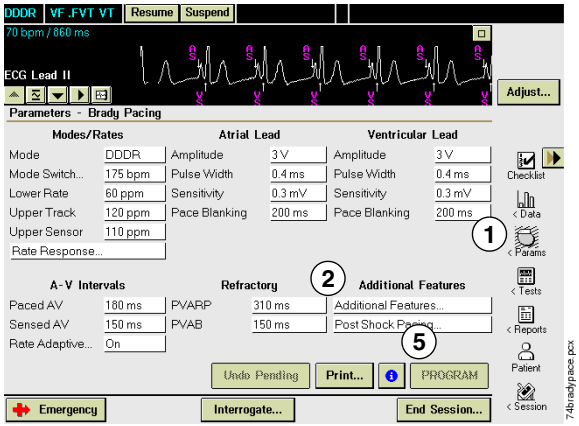
Considerations

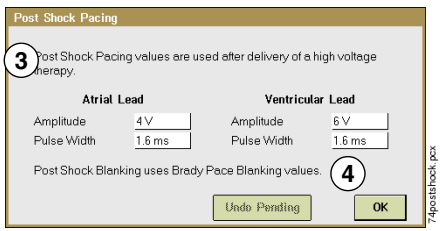
Review the following information before programming Post Shock Pacing.

Adequate safety margin – Considering the post-shock rise in pacing thresholds, be sure to program an adequate safety margin for post shock pacing parameters.

Post Shock Blanking – Brady Pace Blanking values are used for Post Shock Blanking.

How to program pacing after high voltage therapies





1. Select Params icon > Brady Pacing.
2. Select [Post Shock Pacing...].
3. Set the desired atrial and ventricular Amplitude and Pulse Width.
4. Select [OK].
5. Select [PROGRAM].

Details about Post Shock Pacing parameters

Post Shock Pacing is enabled following a high voltage therapy and remains in effect for 25 ventricular events after the therapy is delivered or until the tachyarrhythmia episode ends. Post Shock Pacing also ends if another type of therapy starts.

Post Shock Pacing pulses are delivered as appropriate for the programmed pacing mode. For example, in the AAIR and AAI modes, the Post Shock Pacing pulses are delivered only to the atrium.[1]

[1] For one event after the shock, the device paces in VVI mode.

Key terms

2:1 block rate – lowest atrial rate at which every second atrial event occurs during TARP. The operation results in a ventricular rate one half as fast as the atrial rate.

activity acceleration – programmable time which controls how quickly the device pacing rate responds to increased activity (in rate responsive pacing modes).

activity deceleration – programmable time which controls how quickly the device pacing rate responds to decreased activity (in rate responsive pacing modes).

activity sensor – accelerometer within the device that measures the patient's body motion in rate responsive pacing modes.

activity threshold – programmable rate responsive pacing parameter that defines the minimum level of patient body motion that evokes a rate change.

Atrial Refractory Period (ARP) – programmable refractory period following an atrial paced or sensed event.

atrial tracking – dual chamber pacing operation that paces the ventricle in synchrony with sensed atrial events.

auto-adjusting sensitivity – after each sensed or paced event, the sensitivity thresholds briefly assume less sensitive settings to prevent sensing of T-waves and pacing artifacts.

blanking period – time interval after each pacing pulse, sensed event, or shock, when no sensing can occur.

crosstalk – sensing of a pacing stimulus delivered in the opposite chamber.

escape interval – scheduled time, in milliseconds, between a sensed or paced event and the subsequent pacing output.

event – a sensed or paced beat.

nominal – default programmable parameter value that appears when a feature is first programmed On.

Non-Competitive Atrial Pacing (NCAP) – programmable pacing feature that prohibits atrial pacing within a programmable interval after a refractory atrial event.

Pace Blanking – parameter that disables sensing for a programmable number of milliseconds after each pacing output to avoid inappropriate sensing of artifacts or T-waves.

Paced AV (PAV) interval – programmable delay following an atrial pace that schedules a corresponding ventricular pace.

paced events – output pulses at pacing energy levels from the device.

Pacemaker-Mediated Tachycardia (PMT) – paced rhythm that results when the device senses and tracks retrograde P-waves in DDD or DDDR mode. This retrograde conduction and atrial tracking repeats itself to produce an inappropriately rapid paced rhythm.

pacemaker Wenckebach – see Wenckebach operation.

pacing threshold – minimum programmable pacing output that consistently captures the heart.

PVAB (Post-Ventricular Atrial Blanking) – sets the interval during which sensed atrial events are ignored by bradycardia pacing features.

PVARP (Post-ventricular Atrial Refractory Period) – programmable refractory period used to prevent inappropriate inhibition or PMTs in dual chamber pacing modes.

PVC (premature ventricular contraction) – a sensed ventricular event that directly follows any other ventricular event, with no atrial event between them.

PVC Response – detects a PVC and responds by extending the PVARP to 400 ms (if the currently programmed or Sensor-Varied PVARP is less than 400 ms).

Rate Adaptive AV (RAAV) – dual chamber pacing feature that shortens the AV interval as the heart rate increases.

refractory period – designated period during which the device inhibits its response to a sensed event. Refractory periods help to optimize cardiac efficiency by preventing the disruption of other operations in progress.

retrograde – electrical conduction from the ventricles to the atria.

Sensed AV (SAV) Interval – programmable delay following an atrial sensed event that schedules a corresponding ventricular pace.

sensed event – electrical activity across the sensing electrodes that exceeds the programmed sensitivity threshold.

sensitivity – degree to which a device sense amplifiers are responsive to intra-cardiac voltages.

sensor-indicated rate – pacing rate determined by the patient's level of physical activity and the rate response parameters.

sensor-varied PVARP – a setting for PVARP that is based on the sensor-indicated rate.

Single Chamber Hysteresis – device feature which enables tracking of the patient's intrinsic rhythm below programmed Lower Rate to prevent pacing during extended periods of inactivity, such as when a patient is sleeping.

synchrony – coordinated contraction of the atria and ventricles for most effective cardiac output.

TARP (Total Atrial Refractory Period) – sum of SAV and PVARP in dual chamber pacing modes. When the atrial cycle length is shorter than TARP, every other atrial event occurs in the PVARP and is not tracked.

tracking – see “atrial tracking.”

undersensing – failure to sense the P-wave or R-wave. Undersensing can cause inappropriate bradycardia pacing or a failure to detect tachyarrhythmia.

Wenckebach operation – a dual chamber pacing operation that exhibits dynamic variations in the Sensed AV interval and A:V synchrony. When the atrial rate exceeds the programmed Upper Tracking Rate, it is too fast to be tracked 1:1. The device applies increasing Sensed AV intervals on each atrial cycle, until an atrial event occurs in the PVARP and is not tracked. See also 2:1 block.

Optimizing charge time and device longevity

9

Optimizing charge time 204

Optimizing device longevity 207

Key terms 208

Optimizing charge time

The high voltage capacitors must be formed (or *conditioned*) periodically to maintain quick charging for high voltage therapy. You can use the Automatic Capacitor Formation feature to ensure they are formed regularly.

The device can be programmed to automatically adjust the capacitor formation interval for interactive management of charge time and device longevity.

See details about managing charge time on page 205.

Parameters

* Medtronic nominal setting

Minimum Auto Cap Formation Interval	Auto*, 1 – 6 months

Considerations

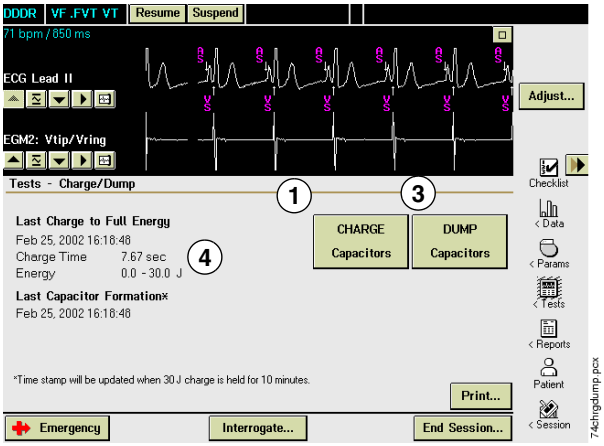
Formation interval and longevity – A shorter formation interval provides faster charge times by optimizing the efficiency of the capacitors. However, each capacitor formation includes a full energy charge, reducing the longevity of the device.

Assess the patient's requirements for faster therapy delivery relative to the effect on device longevity. Each full energy charge decreases the longevity by approximately 24 days.

When you program a new automatic formation interval, always confirm that the charge time is adequate at present. Either perform a manual capacitor formation or evaluate a recent full energy charge time recorded in the Battery and Lead Measurements display.

You can use the Patient Alert monitoring feature to receive prompt notice if a long charge time has occurred.

How to evaluate charging performance



1. Perform a Charge/Dump test, and review the charge time (see page 321).
2. Allow the charge to dissipate for ten minutes.
3. Select [DUMP Capacitors].
4. Perform another Charge Time test, and review the second charge time.
   - If the second charge time is clinically acceptable, consider reducing the Automatic Capacitor Formation interval.
   - If the second charge time is not clinically acceptable, please contact your Medtronic representative.

Details about managing charge time

The device provides the fastest charging and most prompt therapy delivery just following a capacitor formation. During the time between formations, the capacitors gradually lose their efficiency. This results in longer charge times until the next formation.

The charge time also gradually increases over the life of the device as the battery is depleted. This occurs independent of capacitor formation.

Capacitor formation consists of two steps:

1) The capacitors are charged to their full energy.

2) The charge is allowed to dissipate for at least ten minutes.

The device records a timestamp (in the Battery/Lead Status Report) when a full energy charge dissipates for ten minutes without interruption.

Smart Auto Cap

Therapeutic charging can also contribute to the efficiency of the capacitors. This occurs because the capacitors are partially conditioned each time they are charged (for example, during a full energy defibrillation). In these situations, there is less need for the next scheduled capacitor formation.

More frequent formations would decrease the device longevity, with little benefit to the charge time. To optimize the effectiveness of the automatic capacitor formations, the device postpones the schedule when full energy charging has occurred:

- Whenever the capacitor formation interval is reprogrammed, the device resets the automatic capacitor formation interval clock.
- After a manual capacitor formation, the device resets the automatic capacitor formation interval clock.
- After an incidental capacitor formation (a full energy charge that dissipates for 10 minutes), the device resets the automatic capacitor formation interval clock.
- After a full energy charge is delivered or dumped, the device extends the automatic capacitor formation interval clock by up to two months. The total of these extensions will not exceed the programmed automatic capacitor formation interval.

Parameter set to "Auto" – When the capacitor formation interval parameter is programmed to Auto, the device maintains a six month schedule for capacitor formation until the battery is close to end of life.

If a charging period for therapy or capacitor formation exceeds 16 seconds, the device changes to a one month schedule for capacitor formation. If a second charging period exceeds 16 seconds, the device sets the ERI status message, ensuring that the change is reported upon interrogation.

The rules for postponing the scheduled automatic formation after a full energy charge remain in effect if the device changes to a one month schedule.

Optimizing device longevity

The following factors can decrease the longevity of the device:

- a greater number of high voltage charges, either for therapy or for capacitor formation
- higher programmed cardioversion or defibrillation energies
- a greater number of bradycardia paced events, for example, an increase in the pacing rate or use of the Ventricular Rate Stabilization feature
- higher programmed pacing amplitude or pulse width
- a decrease in pacing or HV lead impedance when pacing outputs or stored energy must be increased to compensate
- use of the pre-onset EGM storage or Holter telemetry features
- two-channel EGM storage

For device longevity information, see “Longevity projections” on page 6.

Considerations

Shock energy – If the defibrillation threshold of the patient allows for an appropriate safety margin (at least 10 joules, after the acute implant period), consider programming the first shock energy below the maximum value. Always program all subsequent shocks to the full available energy.

Pacing outputs – If the patient’s pacing threshold allows for an appropriate safety margin (at least a factor of two, after the acute implant period), consider decreasing the pacing outputs. Always consider the patient’s access to regular follow-up care in selecting a safety margin for chronic pacing.

Pacing mode – If the patient’s intrinsic rhythm allows for appropriate rate support, you can decrease the pacing burden by programming the pacing mode, rate response, and AV interval(s) to promote intrinsic activation and/or conduction.

Pre-onset EGM storage – In a patient who uniformly repeats the same onset mechanisms, the greatest clinical benefit of pre-onset EGM storage is achieved after a few episodes are captured.

To maximize the effectiveness of the pre-storage feature and optimize device longevity, consider these programming options:

- Turn pre-storage on to capture possible changes in the onset mechanism following significant clinical adjustments, for example, device implant, medication changes, and surgical procedures.
- Turn pre-storage off once you have successfully captured the information of interest.

Using pre-onset EGM storage reduces longevity by approximately 25% or by 3 months per year.[1]

Key terms

capacitor – electrical component in the device that stores electrical energy, so that a high voltage can be delivered from a relatively small battery.

capacitor formation – any charge to maximum programmed energy that dissipates off the capacitors (is not dumped) for at least ten minutes.

charging period – time required for the device to store the programmed energy (charge) in its capacitors so that it can rapidly deliver a cardioversion or defibrillation therapy.

longevity – number of years before the device battery is depleted.

[1] Based on device modeling at 15% pacing and quarterly full energy charges.

Part IV

Evaluating and managing patient treatment

Using the programmer

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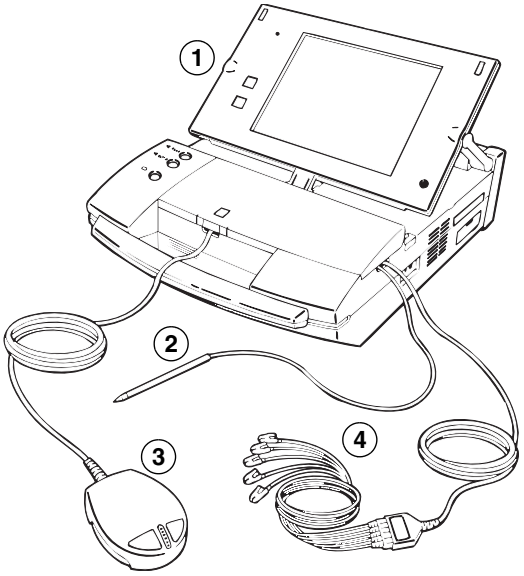
Connecting the programmer hardware

The following sections summarize the basic steps for setting up the 9790c programmer. For more complete information, refer to the manual supplied with the programmer. Figure 10-1 shows the main components of the 9790c programmer system.

Figure 10-1. Programmer hardware components



1 9790c Programmer

2 Touch pen (stylus)
Note: Do not disconnect the touch pen.

3 9767/9767L programming head[a]

4 ECG Cable

[a] For information about installing the 9767 or 9767L programming head, see the manual accompanying the programming head.

Input/Output ports: keyboard, parallel, serial, and VGA –

- Keyboard, used by Medtronic personnel when servicing the programmer.
- Parallel Port, used with an external printer.
- Serial Port, for future use.
- VGA port, can be used to port the screen image of the programmer to an external VGA monitor or for conversion of the output signal to NTSC/PAL format for presentation on a television monitor. Please contact Medtronic Technical Services at 1-800-328-2518 for technical guidance.

△ **Caution:** To protect against interference or surge/leak currents, the use of a secondary VGA monitor that meets an applicable safety standard such as UL 1950 or IEC 950 is strongly recommended.

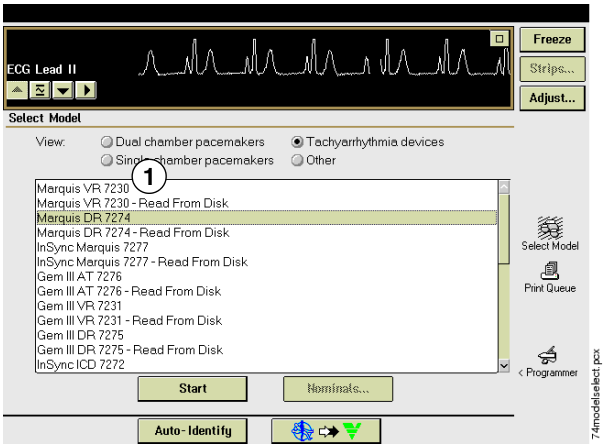
Using an external printer

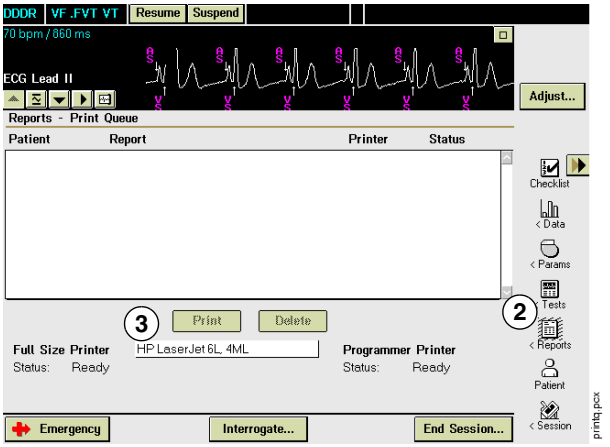
Connecting a compatible printer to the programmer allows you to print full, page-size reports of session data when available. This section describes how to connect a printer to your programmer.

Note: All printers listed by this software are certified to IEC 950 except for the Canon Bubble Jet™ 230 (used in the United States). Only printers listed by this software may be connected to the programmer. It is the responsibility of the user to keep the printer at least two meters away from the patient.

The programmer is compatible with many printers. A list of compatible printers can be accessed from the Print Queue screen.

To view a list of supported printers





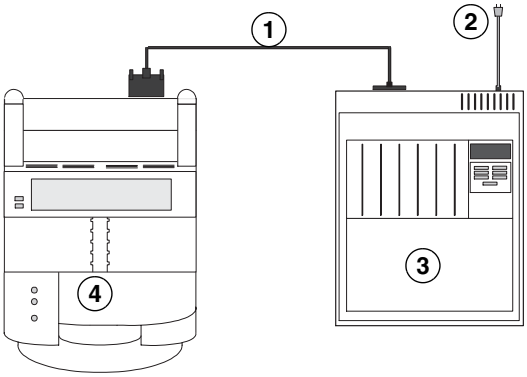
1. Select Marquis DR 7274 from the Select Model screen.
2. Select Reports > Print Queue.
3. Select the Full-Size Printer field to display the list of supported full-size printers.

Materials you will need

To connect a printer to the programmer, you will need a Parallel Interface printer cable. One end of the cable must fit the parallel interface port on your printer. The other end of the cable must be a standard 25-pin male D connector. Most parallel printer cables are of this type.

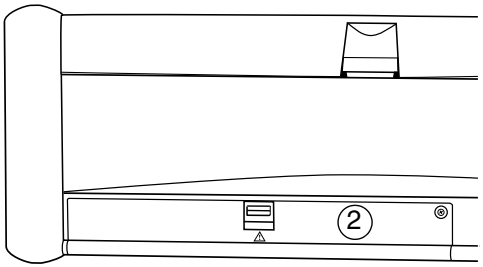
You will also need a small Phillips screw driver to open the parallel port access panel on the back of the programmer.

Figure 10-2. Printer Connection Diagram

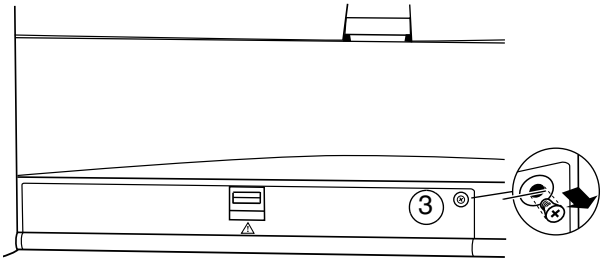


1 Parallel printer cable
2 Printer power cord
3 Printer
4 Programmer

To connect the printer to your programmer

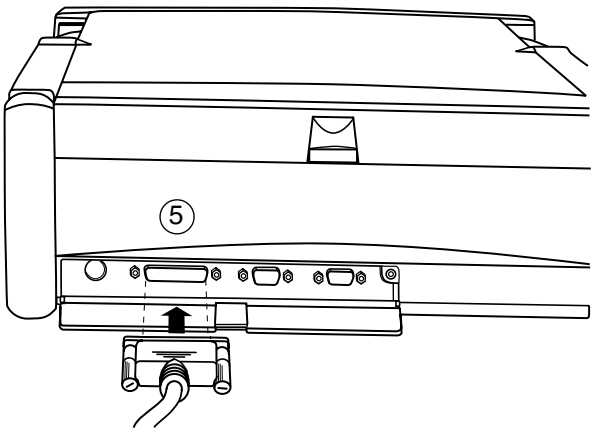


1. Exit the patient session and turn the programmer off.
2. Locate the parallel port access panel on the back of the programmer.



3. Remove the small Phillips head screw in the upper right corner of the access panel.

4. Open the access panel by pushing downward on the small latch at the top center of the panel.



5. Connect the printer cable to the parallel port on the programmer.
6. Connect the other end of the cable to the printer. Connect the printer power cord to an appropriate power outlet and turn the printer on. Make sure that the printer has been loaded with paper.

   Note: Refer to the technical information provided with your printer for information about connecting and operating the printer.
7. Turn the programmer on and select the Print Queue icon.

Using the programming head

When the programming head is placed over the device and telemetry is established, the amber light on the programming head turns off, and one or more of the green indicator lights turn on. You can find the optimum position for the programming head by moving it around the implanted device until the greatest number of green lights turn on. To ensure proper telemetry, make sure to position the programming head so at least two of the green lights are on.

If the programming head slides off the patient, the session is not terminated. Place the programming head back over the device to resume programming or interrogating the device.

Notes:

- Any successful interrogation or programming verifies proper communication between the device and the programmer.
- The programming head contains a magnet that can suspend tachyarrhythmia detection. However, if telemetry between the device and programmer is established, detection is not suspended.

During an episode in progress

If you position the programming head over the device when a detected arrhythmia episode is in progress, the device detects and treats the arrhythmia normally, provided telemetry between the device and the programmer can be established. If telemetry cannot be established, the magnet inside the programmer head causes the device to suspend detection.

During marker transmissions

The device continuously transmits Marker Channel and Marker Supplement data via telemetry while the programming head is positioned over the device.The device stops these transmissions when you lift the programming head unless the Holter Telemetry feature is programmed on. (If Holter Telemetry is programmed on, the device transmits telemetry regardless of the position of the programming head.)

How capacitor charging affects the light array

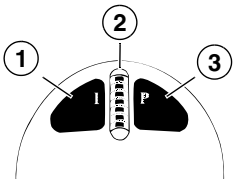
The programming head indicator lights may turn off during high voltage capacitor charging periods. This results from interference generated by the charging circuit and is normal.

Alternative program and interrogate buttons

The programming head provides two buttons that you can use to program [P] or interrogate [I] the device (see Figure 10-3). These buttons are active only when [PROGRAM] and [Interrogate] are displayed as active buttons on the display screen.

Note: The programming head [P] and [I] buttons are disabled during EP study inductions.

Figure 10-3. Programming head



1 Interrogate button
2 Telemetry light array
3 Program button

Display screen features

The programmer display screen is an interactive device that displays text and graphics. It is also a control panel that displays buttons and menu options that you can select using the touch pen.

This section provides an overview of the features of the display screen. Figure 10-4 shows the main elements of a typical display screen.

Figure 10-4. Main elements of a display screen

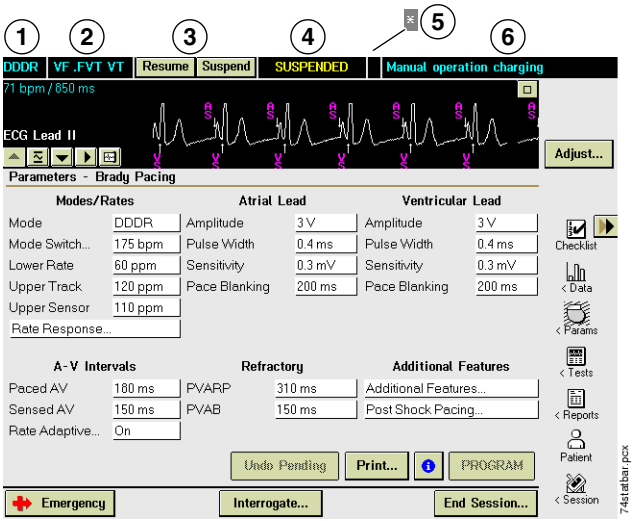
1 Status Bar
2 Live Rhythm Monitor Window
3 Task Area
4 Command Bar
5 Tool Palette

Note: For information on changing the language (for example, from English to German), see page 228.

Programmer status bar display

Once the device has been interrogated, the status bar at the top of the displayed screen provides some basic functions and current status of the device.

Figure 10-5. Status bar display



1 Currently active brady pacing mode
2 Programmed detection and therapy configuration
3 Buttons used to Resume or Suspend detection
4 Automatic detection status
5 Indicates that an episode is in progress
6 Current episode, therapy, or manual operation status

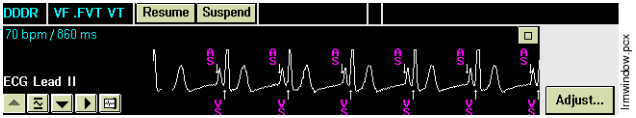
Live Rhythm Monitor window

The Live Rhythm Monitor window is a partial view of the full-screen display of ECG, Marker Channel, and telemetered EGM waveform traces. You can expand this window to its full size by selecting the small square button in the upper-right corner of the window or by selecting the [Adjust...] button.

- Heart rate and rate interval are displayed if the programming head is positioned over the ICD.
- Annotations above the waveform trace show the point of programmed parameter changes.

For more information about the Live Rhythm Monitor, see “Viewing live waveforms” on page 233.

Figure 10-6. Live Rhythm Monitor window



The waveform trace or traces displayed in this window depend on the selected task screen and how traces have been arranged in the full-screen view.

Task area

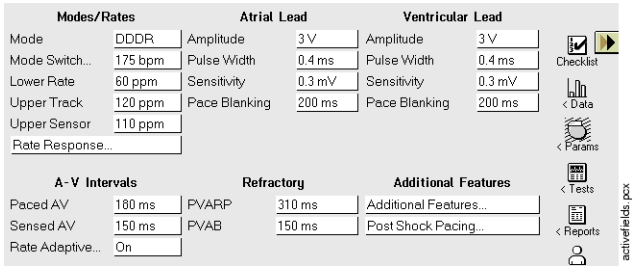
The portion of screen between the live rhythm monitor window (top of screen) and the command bar (bottom of screen) changes according to the task or function you select.

The example in Figure 10-4 shows the Detection screen, which is used to program detection parameters. The task area would be different for a Parameters screen or Tests screen, for example.

Active fields

Unshaded areas, or boxes, appearing in the task area are “active fields” that respond to the stylus.

Figure 10-7. Active fields displayed as unshaded areas on the screen

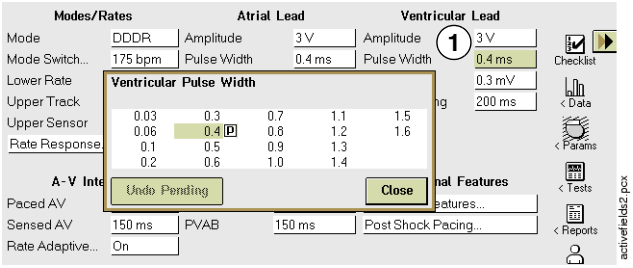


Selecting a value, word, name, or phrase that appears in an active field opens a menu or window of alternative options for whatever is represented in that field.

For example, touching the pulse width value 0.4 ms in the Ventricular Lead field with the tip of the stylus opens a window of pulse width value options. Selecting any one of these options replaces the original value with the selected one.

Selecting some fields (those with terms ending in an ellipsis, such as Rate Response...) opens a window displaying additional fields.

Figure 10-8. Selecting an active field

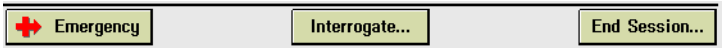


1 Selecting the Pulse Width field opens a window of alternative parameter values.

Command bar

The bar at the bottom of the screen always shows the buttons for programming Emergency parameters, interrogating the ICD, and ending the patient session.

Note: The [Interrogate] and [End Session] buttons do not appear on the Emergency screen.

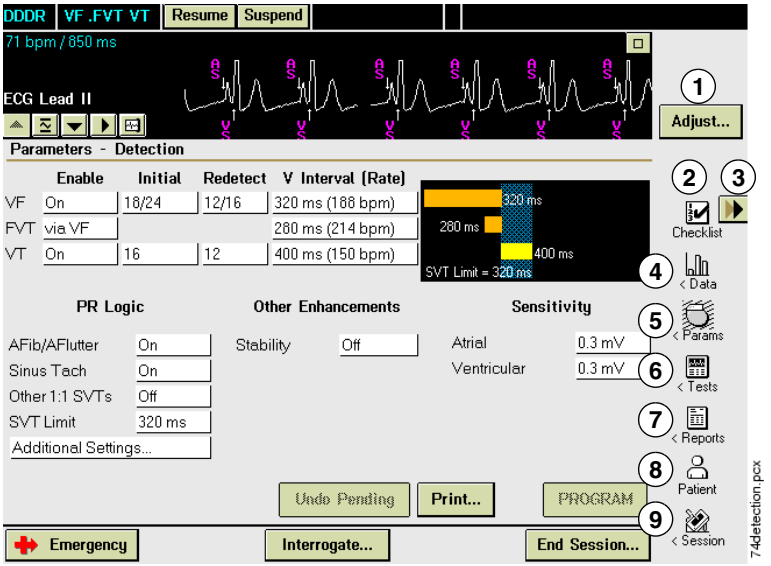


Tool palette

The buttons and icons along the right edge of the screen are referred to as the “tool palette.” Use these tools to display a task or function screen. After starting a patient session, the tool palette is displayed on all but the Emergency or Live Rhythm Monitor Adjust... screens, making it quick and easy to move to the desired task or function.

Each of the icons acts like a button. To select an icon, touch the icon with the stylus. Figure 10-9 describes each option in the tool palette.

Figure 10-9. Tool palette options



1 **[Adjust...] button:** opens a window of options for adjusting the Live Rhythm Monitor display (see page 233).

2 **Checklist icon:** opens the Checklist screen for simplified navigation through a set of programmer related tasks (see page 261).

3 **Checklist double-arrow button:** navigates to the next programmer screen in the active Checklist (see page 261).

4 **Data icon:** displays options for retrieving information about the device and for setting up the data collection and Patient Alert functions.

5 **Params icon:** displays options for programming device parameters.

6 **Tests icon:** displays options for performing system tests.

7 **Reports icon:** displays options for printing reports (see page 246).

8 **Patient icon:** displays the Patient Information screen (see page 301).

9 **Session icon:** displays options for ending the session, saving interrogated data, and viewing changes made during the session.

Buttons

Buttons like those shown below let you operate the programmer using the stylus. You can “press” a button by touching it with the tip of the stylus.

Figure 10-10. Display screen buttons

1 Buttons having a less distinct shaded label are not presently active

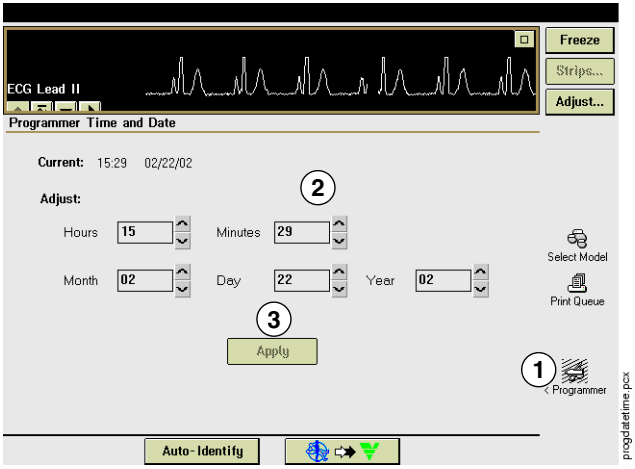
Buttons may directly execute a command, such as the [Program] button, or they may open a window that prompts another action. Usually such buttons have a label ending with an ellipsis, such as the [Interrogate...] or [End Session...] buttons shown above.

A procedure may instruct you to “press and hold” a button. In such cases you should touch the tip of the stylus to the button and continue to maintain pressure against the button until it is time to “release” the button.

Setting programmer preferences

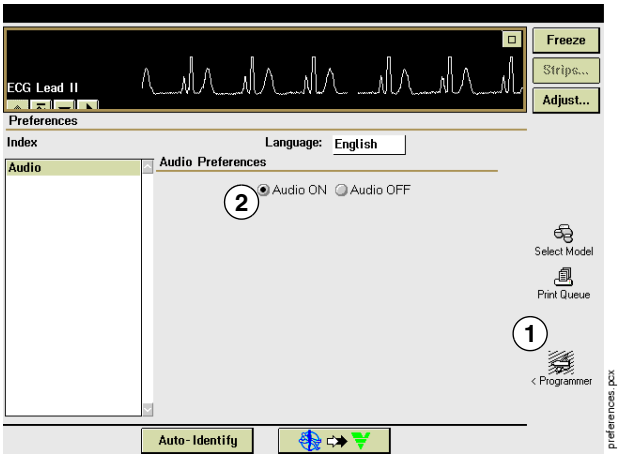
Before you start a patient session, you can set the programmer time and date, set audio preferences, select a different language for the software display, and check the software version number. Once you have started a patient session, you can also set printing preferences and reports preferences.

How to set the programmer time and date



1. Select Programmer > Time and Date.
2. Select the ⩿ or ⩾ button to increase or decrease the value for the unit of time you want to change.
3. When all fields show the correct time and date, select [Apply].

How to set audio preferences

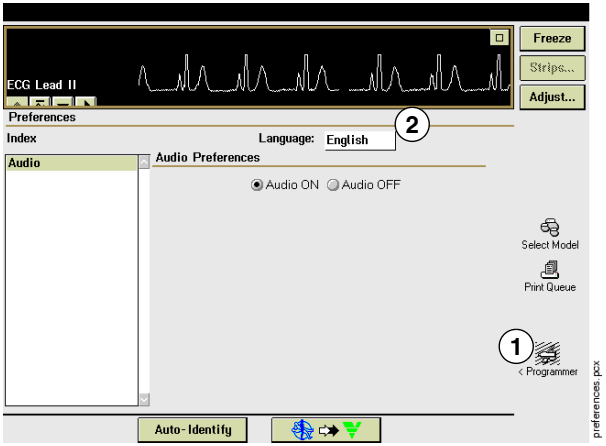


1. Select Programmer > Preferences.
2. Select [Audio ON] or [Audio OFF] button as desired.

Certain events in the operation of the programmer result in an audible signal. The following tones alert the user to the success or failure of an action.

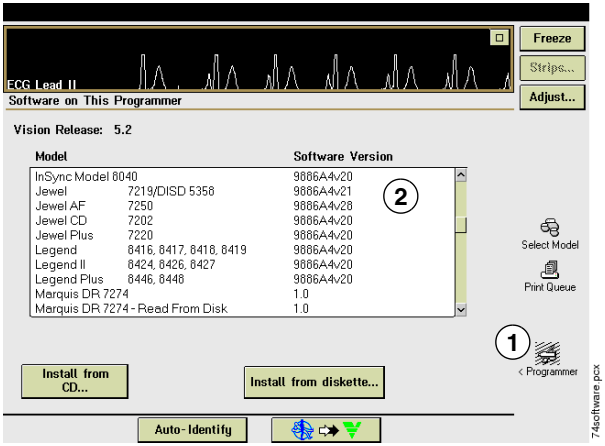
- A two-tone beep (low-to-high) indicates confirmation of an Interrogate or a Program command.
- A double low-tone beep indicates that an Interrogate, Program, or Emergency command was **not** confirmed. It can also indicate that the selected command cannot be executed.
- A single, short beep coincides with pressing the Interrogate or the Program button. It also occurs upon automatic identification of the ICD.

How to select a different language



1. Select Programmer > Preferences.
2. Select a value for the Language parameter.

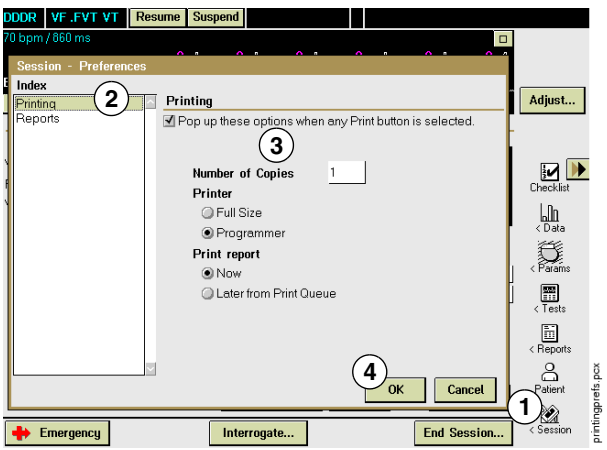
How to check the software version number



1. Select Programmer > Software.
2. Scroll through the software applications listed on the Software on This Programmer screen.

   For each software application loaded on the programmer, the screen displays the software version number next to the model number.

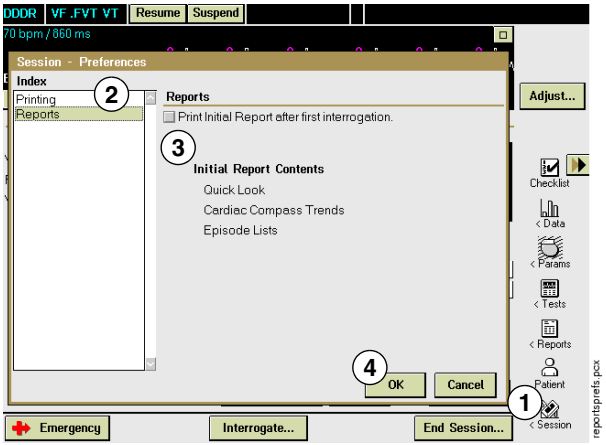
How to set printing preferences



1. After you've started a patient session, select Session > Preferences.
2. From the Index selection box, select the Printing option.
3. Set the printing preferences as desired.
4. Select [OK].

The Printing preferences allow you to select the number of copies, default printer, and whether to print now or later. If you deselect the checkbox next to "Pop up these options when any Print button is selected," the programmer automatically applies these default print preferences each time you select [Print] during a patient session.

How to set reports preferences



1. After you've started a patient session, select Session > Preferences.
2. From the Index selection box, select the Reports option.
3. Set the reports preferences as desired.
4. Select [OK].

The Reports preferences let you enable or disable the automatic printing of an Initial Report after the first interrogation of a patient session. The contents of the Initial Report are not selectable, but are listed on the Reports preferences screen.

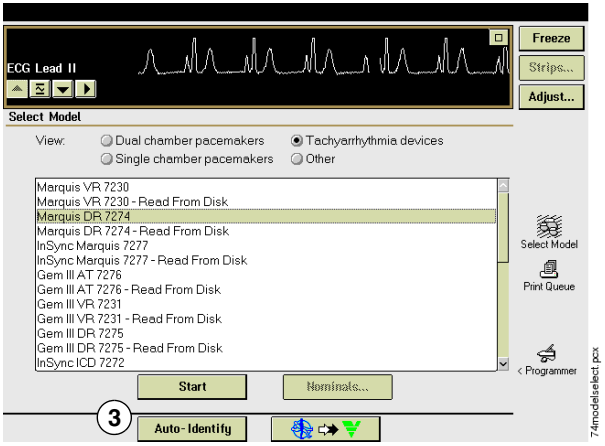
Starting and ending patient sessions

Because the programmer collects and stores data on a session-by-session basis, it is important to correctly start and end each session. You should not begin using the programmer with a different patient until you have completed this procedure.

If the programmer detects a device serial number that is different from the one acquired during the initial interrogation, it automatically requests that you end the current session.

Note: Connect the programmer skin electrodes to the patient if you would like to display a surface ECG signal from the programmer. See the user manual for your programmer for more information.

How to start a patient session

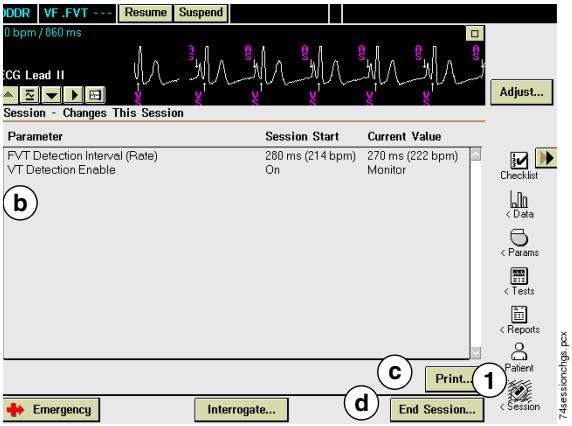


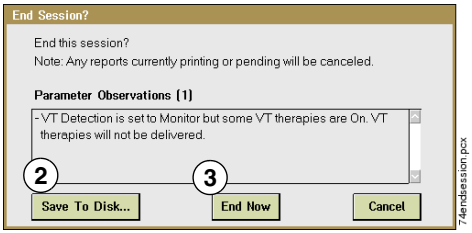
1. Display the Select Model screen:

   If the programmer is on, but the Select Model screen is not displayed, you need to end the current session before starting a new one.
2. Position the programming head over the patient's device, and hold it steady. The best position for telemetry is when the greatest number of green indicator lights are on.
3. Select the [Auto-Identify] button at the bottom of the screen or press the [I] programming head button.

   The programmer loads the appropriate software application and displays the Quick Look screen and immediately begins to interrogate the device.

How to end a patient session




End Session?
End this session?
Note: Any reports currently printing or pending will be canceled.
Parameter Observations (1)
- VT Detection is set to Monitor but some VT therapies are On. VT therapies will not be delivered.
2
3
Save To Disk...
End Now
Cancel
74endsession.pcx

Ending a Patient Session

1. Select the Session icon > End Session.
   a. If you want to review or print a list of changes made during the last session, select Session icon > Changes This Session.
   b. Review the programming changes made during the patient session.
   c. Select [Print] to print a record of the changes or select [Cancel].
   d. Select [End Session].
2. Select [Save To Disk...] to save session data to a disk.[a]
3. To end the session and return to the Select Model screen, select the [End Now] button.

[a] For information about saving data to a disk, see page 242.

Automatic interrogation

After starting the programmer and placing the programming head over the device, select [Auto Identify] or select the device from the displayed list and select [Start]. The programmer automatically starts the software application and interrogates the device.

All non-emergency programmer functions are unavailable during an interrogation.

Viewing live waveforms

The live rhythm monitor window normally displays a live ECG waveform at the top of most programmer screens.[1] This waveform display can be adjusted and customized using the Adjust window and the waveform adjustment button bar.

For details about live waveforms, see page 235.

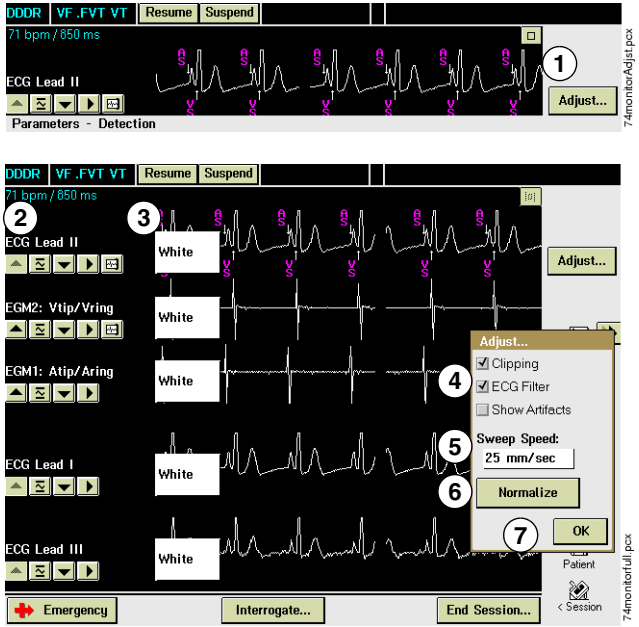
Parameters

* Medtronic nominal setting

Clipping – truncates the tops and bottoms of waveform traces at a 22 mm boundary.	enable*, disable
Sweep speed – sets sweep speed. (mm./sec.)	12.5, 25*, 50, 100
ECG Filter – changes the bandwidth of waveform to improve the clarity of the displayed ECG in the presence of interference. (check box)	disable 0.05 to 100 Hz enable* 0.5 to 40 Hz
Show Artifacts – displays pacing artifacts superimposed over waveforms. (check box)	enable, disable*
Normalize – equalizes the spacing between the traces and adjusts the size of each trace to the default setting.	

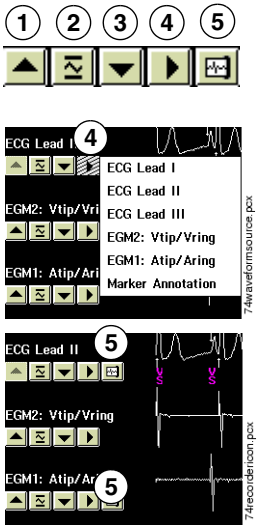
[1] When ECG inputs are connected to the programmer.

How to use the Adjust window



1. Select [Adjust] to display the full screen Live Rhythm Monitor and the Adjust window.
2. Adjust the size, source, or print selection options for each waveform trace using the waveform adjustment bar.
3. Select the color field in the waveform trace area to change the color of a waveform.
4. Select [Clipping], [ECG Filter] and [Show Artifacts] to enable or disable these options as desired.
5. Select the Sweep Speed if desired.
6. Select [Normalize] to equalize the trace spacing and adjust the size of each trace to the default setting.
7. When you are finished making adjustments, select [OK].

How to use the waveform adjustment button bar



1. Select the up arrow button to increase the size of the waveform.
2. Select the Normalize button to restore the waveform to its default size.
3. Select the down arrow button to decrease the size of the waveform.
4. Select the Waveform Source button to select the source of the waveform to be displayed.
5. Select the Waveform print selection button to enable or disable the waveform for printing. Up to two waveforms can be selected.

Details about the live rhythm monitor

This live rhythm monitor can display up to six different waveforms during a patient session:[1]

- ECG leads I, II, and III are available when you attach ECG leads to the patient's skin and connect them to the programmer.
- Marker annotations showing device operations are telemetered from the device to the programmer when the programming head is over the device.
- EGM1 and EGM2 signals are telemetered from the device and are based on the two programmable EGM sources. See "EGM source" on page 269.

  The programmer cannot display (or record) an EGM trace until the current EGM Range setting has been interrogated from the device.

[1] To adjust the size of this display and arrange the traces displayed, see page 235.

Table 10-1. Waveform trace information

Trace	Description
ECG Lead I ECG Lead II ECG Lead III	ECG signals are detected via skin electrodes attached to the patient. The programmer must be connected to these electrodes with the ECG cable.
Marker Annotations	Marker annotations indicate triggered events such as pacing, sensing, detection, and delivered therapies.
EGM1 EGM2	EGM signals are telemetered from the device and are based on the two programmable EGM sources.

Note: A single waveform is displayed for most windows. A dual-waveform window is displayed for EP Study, System Test, and Emergency screens.[1]

Marker Channel telemetry annotations

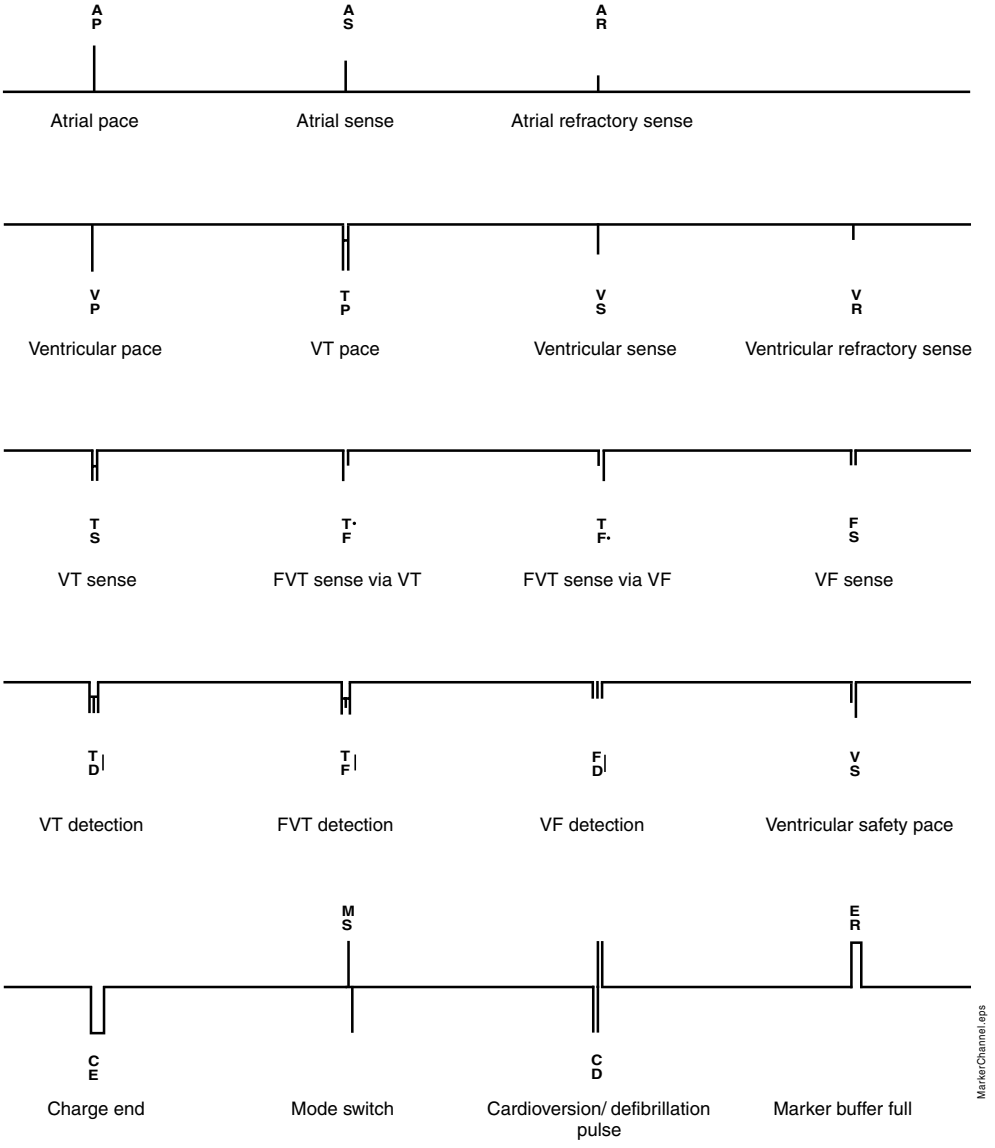
Marker Channel telemetry annotations appear as two characters above or below the Marker Channel trace of the waveform display.[2] These annotations indicate events such as pacing, sensing, detection, and delivered therapies (see Figure 10-11).

In addition to annotations, the Marker Channel trace uses symbols to indicate specific events. Marker channel symbols appear only on real-time waveform recordings, not on screens or in episode recordings. These symbols sometimes appear compressed, depending on the printout speed of the programmer strip chart recorder.

Note: Since the displayed waveforms depend on telemetry received from the device, marker annotations are not displayed unless the programming head is positioned over the device. Therefore, any interruption in telemetry may result in missing markers on the trace display.

[1] The single trace display provides the trace from the top of the live rhythm monitor sources; the dual display shows the top two traces.
[2] By default, Marker Channel annotations are superimposed over the ECG trace displayed at the top of most programmer screens.

Figure 10-11. Marker Channel symbols and annotations



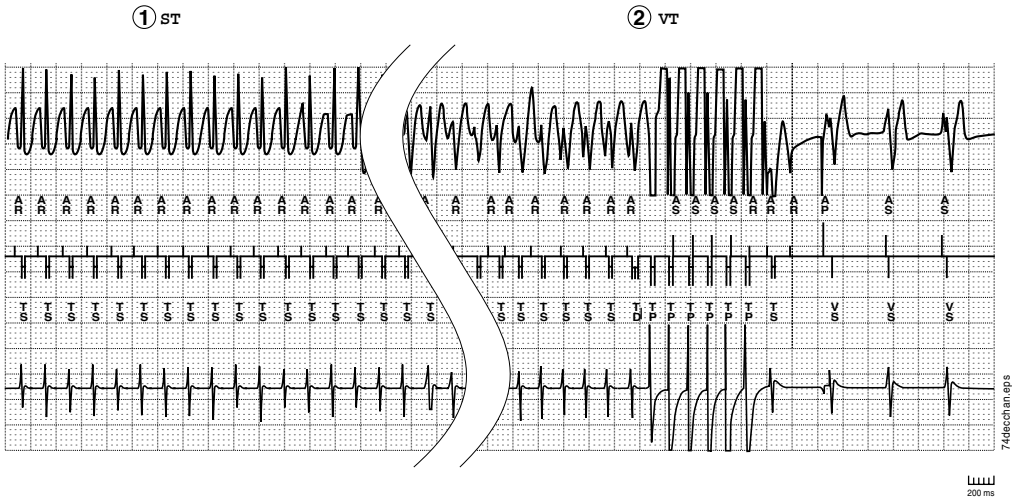
Decision Channel annotations

Decision Channel annotations provide supplementary information about the operation of device detection algorithms, as shown in Figure 10-12. Decision Channel annotations are saved with the EGM data for episode records and printed on real time recordings (see Table 10-2).

Table 10-2. Decision Channel annotations

Situation	Episode record / Real time recording
VF detected or redetected	VF
FVT detected or redetected	FVT
VT detected or redetected	VT
VF+SVT double tachycardia detected	VF+SVT
FVT+SVT double tachycardia detected	FVT+SVT
VT+SVT double tachycardia detected	VT+SVT
High rate timeout	HT / High Rate Timeout
VT Monitor	VTM / VT Monitor
Stability Criterion reset VT NID	Reset: Stability
A.Fib/A.Flutter rule withholds detection	AF
Sinus Tachycardia rule withholds detection	ST
Other 1:1 SVTs rule withholds detection	SV
A PR Logic criterion is active but the NID criterion is no longer met, or a PR Logic criterion becomes inactive.	none/--

Figure 10-12. Decision Channel annotations on a real-time recording



Decision Channel annotations indicating:

1 Sinus Tach SVT detection criterion is active

2 VT detected

PR Logic criteria annotations – PR Logic criteria annotations (AF, ST, and SV) are displayed if either the VTNID or the VFNID criterion is met, and detection occurs or is withheld by a PR Logic criterion. These annotations are displayed differently on the real time recording than they are in the stored episode record data.

- On the real time recording, PR Logic criteria annotations are printed when one of the following is true:
  - detection is first withheld by a criterion
  - real time recording is initiated when a criterion is already withholding detection
  - if a criterion currently withholding detection changes
- In the stored episode record, PR Logic criteria annotations are recorded and displayed under every event during which a rule is active.

If more than one PR Logic criteria is withholding detection, only annotations for the highest priority criteria are printed. The order of priority from highest to lowest is A.Fib/A.Flutter, Sinus Tachycardia, Other 1:1 SVTs.

Recording live waveforms

At any time during a patient session, you can start a continuous, live recording of the patient's ECG and EGM[1] from the programmer strip chart recorder.

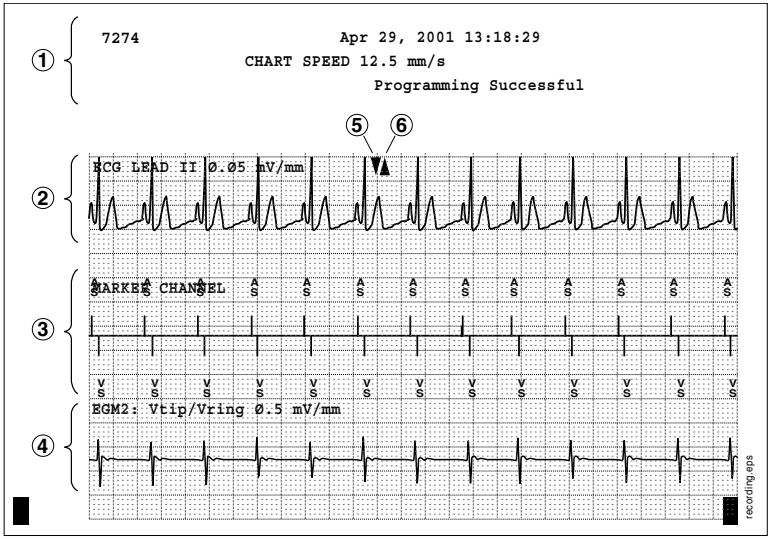
Note: Because the printed recording provides a higher resolution, it may show artifacts and events that do not appear on the programmer display.

A printout of the live ECG includes

- ECG and EGM traces
- an indication of an executed command when confirmation of the command is received
- test values during a Pacing Threshold test
- EGM Amplitude Test
- transmission markers that show active transmissions between the device and the programmer
- any change in EGM source range setting, which is marked with a vertical dotted line and the new gain setting
- Decision Channel annotations

[1] The programmer cannot record an EGM trace until the device been interrogated.

Figure 10-13. An example of a live waveform recording



1 Annotations
2 ECG trace
3 Marker Telemetry
4 EGM telemetry
5 Telemetry from programmer to device
6 Telemetry from device to programmer

Printing a report while recording live ECG

If you select an option from the Print menu while recording a live ECG, the report goes to the print queue. Alternatively, if you start a live ECG recording while the programmer is printing a report, the report stops printing and is sent to wait in the print queue.

Note: This applies only to reports printed on the programmer strip chart recorder. Printing to a full-size printer is not affected.

Automatic telemetry attempts

If telemetry between the programmer and device is not successful, the programmer automatically retries an attempted transmission up to two times. This may result in multiple sets of programming and confirmation indicators being recorded.

EGM and Marker Channel telemetry

The programmer cannot record an EGM trace until the current EGM Range setting has been interrogated from the device.

If you program an EGM Range setting during a recording, the programmer marks the change with a vertical dotted line on the paper recording and annotates it with the new gain setting.

EGM and Marker Channel telemetry can be momentarily interrupted during an interrogation or programming or during capacitor charging.

Saving and retrieving device data

The programmer allows you to copy interrogated data to a diskette. Data saved on a disk can be accessed by the programmer via the Read From Disk application.

Considerations

Review the following information before saving data to a disk:

⚠ **Warning:** The Read From Disk Application is designed for viewing saved data only. You cannot program the device or deliver Emergency therapies from the Read From Disk Application.

Emergency functions while saving – During the save operation, the [Emergency] button remains displayed, and all Emergency functions are available. If a disk error occurs during a save, there may be a delay in initiating the Emergency screens.

Therefore, it is suggested that you not save to disk during EP studies or when a possibility exists that Emergency functions might be needed immediately.

Emergency functions while reading – You cannot perform emergency operations from the programmer while in a Read from Disk session.

Interrogate first – Make sure to interrogate the device before saving data to a diskette, because the programmer saves only the data it has interrogated. If you wish to save all of the information from the device, select the All option from the interrogation window.

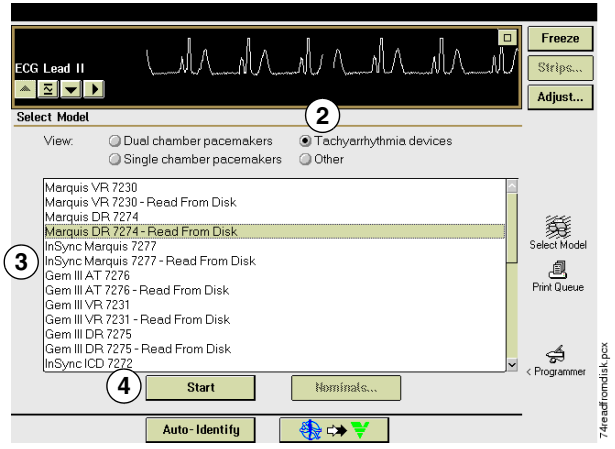
Ejecting disk – Do not eject the diskette from the drive while a save is in progress. This can cause a disk error to occur.

How to save ICD data to a disk

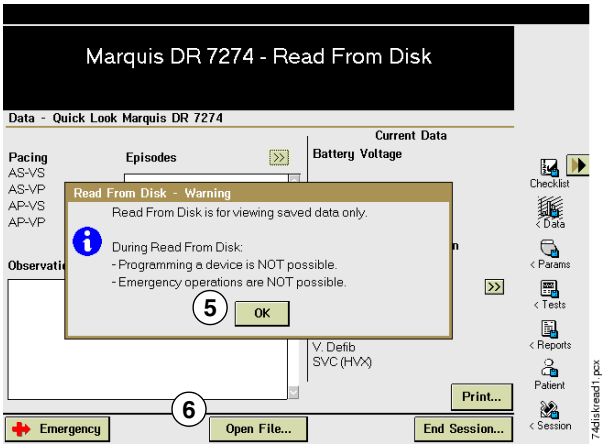
1. After interrogating the device, select the Session icon > Save to Disk... .
2. Insert a diskette into the programmer floppy disk drive.
3. Select [Save].

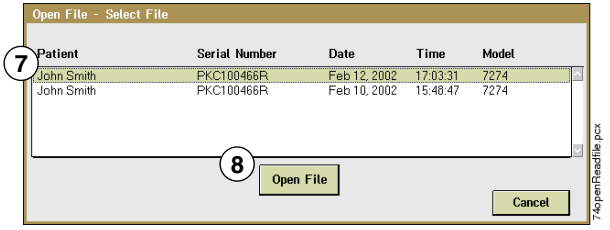
   Note: You also have the option to Save to Disk when you select [End Session...].

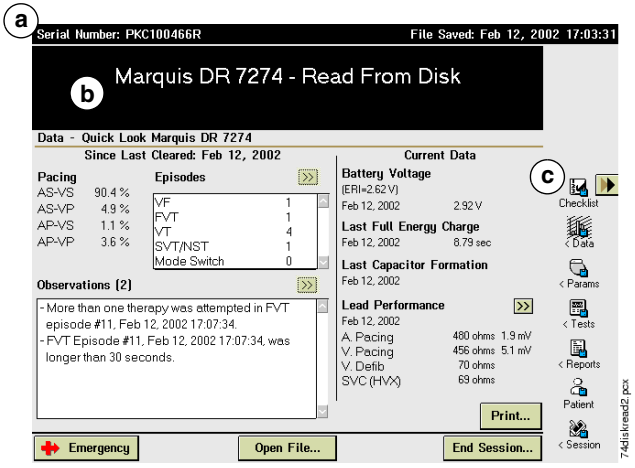
How to read ICD data from a disk



1. Insert a diskette that contains previously saved information.
2. From the Select Model screen, select Tachyarrhythmia Devices.
3. Select Marquis DR 7274 - Read From Disk.
4. Select [Start].







5. Select [OK] from the warning message.
6. Select [Open File].

   Caution: Do not remove the diskette from the drive while the Please Wait... message is displayed. Doing so will disable the programmer disk drive. To restore disk drive function, you must restart the programmer by turning it off and back on again.
7. Select the data record that displays the desired device serial number, date and time.
8. Select [Open File].

   Notice the differences between a patient session and a read from disk session:
   a. Status bar displays device serial number of data file.
   b. No live rhythm monitor is displayed.
   c. Icons indicate disk session.

Saving data to a disk

The disk you use for saving data from the programmer must be

- a formatted, IBM-compatible, 3.5 inch diskette
- 720 KB (DS, DD) or 1.44 MB (DS, HD)

If you save data to a disk that is corrupt or is not IBM-formatted, the programmer could become unresponsive. If this occurs, turn the programmer off and then on again. Normal operation should resume. Please inform your Medtronic representative of this occurrence.

Data file names

Saved files are automatically named with a file name representing the date and time the file was saved, for example, filename: DDHHMMSS.PDD where

DD represents the day of the month (01 to 31)

HH represents hours (24 hour clock)

MM represents minutes

SS represents seconds

PDD is the extension for the programmer data file

Reading device data from diskette

When reading data from a diskette, information is presented using the same user interface as programming a device. You can view the saved data, print reports, and display all programmed parameter values. You cannot program the device or perform tests on the device when reading data from a diskette.

Printing reports

Information collected by the device is available in several report options. You can print either a Full Summary report or a Custom report.

Select [Full Summary] from the Reports icon to print a report that includes all the following information:

- Parameter Summary Report
- Parameter Settings Report
- Status Report
- Counters Report
- Episode Lists Report
- Cardiac Compass Report

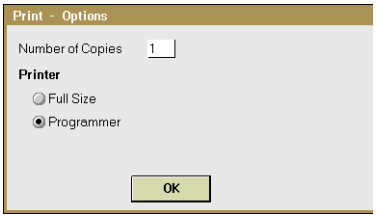
If you would like to choose which information categories to include in the printed report, select [Custom ...] from the Reports icon.

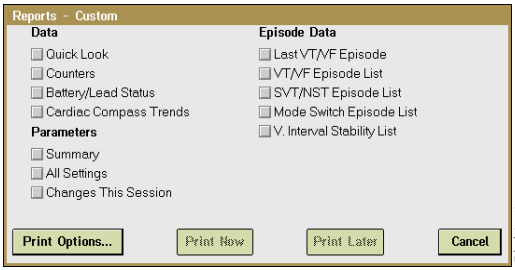
Other reports can be printed from individual programmer screens by selecting [Print] from the displayed screen, including but not limited to the following reports:

- Quick Look
- Counters
- Battery/Lead Status
- Parameter Summary
- Parameter Settings
- Changes This Session
- Last VT/VF Episode
- VT/VF Episode List
- SVT/NST Episode List
- Mode Switch Episode List
- Ventricular Interval Stability List

For more information about setting up an external printer, see the user guide for your Medtronic programmer.

How to print a report





1. To print a report from the displayed screen, select [Print...].
2. To print a report, select the Reports icon and select Full Summary... or Custom....

Print Options:

1. Select the Number of Copies.
2. Select the Printer. The default printer is the Programmer.
3. If you want to print to a connected full size printer, select Full Size and select a print driver.

   Note: You can only print to a full-size printer only during a patient session.
4. Select [Print Now] for immediate printing, or select [Print Later] to add the print request to the Print Queue.

Print Queue

When printing, if you select [Print Later], the print job is held in the Print Queue. Select the Reports icon to display the Print Queue window. From this window you can check the status of a print job and either print or delete a print job from the queue. A report cannot be deleted if its status is “printing” or “waiting.”

The print queue Status column lists the print status for each report:

- Printing: Indicates that a report is currently printing.
- Deleting: Indicates that report is currently being deleted (via the [Delete] button).
- Waiting: Indicates that a report is waiting for another report to finish printing.
- Hold-Later: Indicates that a report is on hold until you request that it be printed (via the [Print] button). A Hold-Later status could also mean that a report was interrupted by the start of a recording or the printer is not operational (because it is out of paper, for example).
- Done: Indicates the status of print job.

Key terms

Decision Channel telemetry – annotations displayed on stored EGMs and telemetered waveforms which document certain details of dual chamber tachyarrhythmia detection.

EGM strip – stored recording of the intracardiac waveforms from a detected arrhythmia episode.

Interrogate – command to transmit the device parameters and stored data to the programmer.

Last Session – most recent time the ICD was successfully interrogated. A session ends eight hours after the last interrogation.

live rhythm monitor – programmer display of telemetered ECG, Marker Channel, and EGM waveforms on one screen or a partial-screen window.

Marker Channel telemetry – telemetered symbols that annotate the ICD sensing, pacing, detection, and therapy operations.

waveform – graphic plot of electrical activity, for example, intracardiac EGM or surface ECG trace.

Using system evaluation tools

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Key terms 264

A summary of system evaluation tools

Several software features are available to evaluate the ICD system performance and monitor the interaction between the patient and device. During patient follow-up visits, these features provide feedback on the patient's cardiac activity and device operation.

Table 11-1. Evaluation tools

Automatically set up

Quick Look - a summary of patient and system information since the last patient session.

Episodes and counters - a set of screens that provide a count of detected episodes and therapy results.

Battery and lead measurements - display of automatic battery, lead, and capacitor measurements. These results are also used in reports.

Reports - screen display and printable reports for recording device data.

Changes this session - screen display of parameter changes between the start of a patient session and currently interrogated values.

Requires initial set up

Patient Alert - an audible device alert that alerts the patient that one or more specific events have occurred. The patient is instructed to contact their physician or clinic if they hear a patient alert.

Checklist - an organized list of programmer screens used to perform standard or customized tasks. The checklist can be used as a reference list or as a means to track which steps have been completed for a specific task.

Patient information - a screen used to collect and display information about the patient's cardiac medical background, device leads, and physician.

Automatic daily measurements

Automatic daily measurements are performed to measure EGM amplitudes, lead impedance, and battery voltage. See "Daily lead impedance and EGM amplitude measurements" on page 274 for more information on these daily measurements.

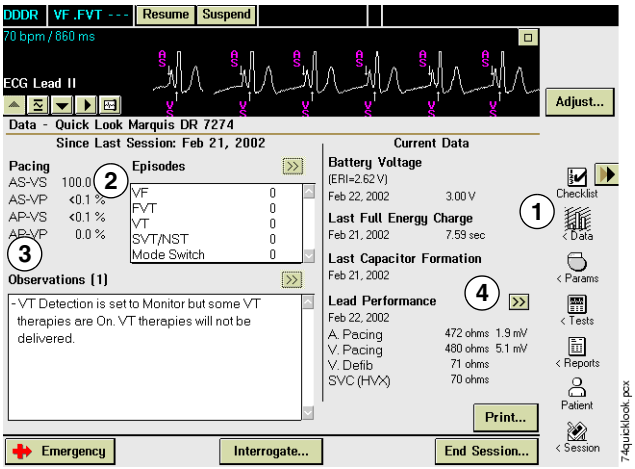
Taking a quick look at device activity

The Quick Look screen provides a summary of the episode data and battery/lead status information gathered since the last patient session.

Note: The Quick Look screen is automatically displayed after an initial device interrogation. To display changes during a session, re-interrogate the device, and select Quick Look from the Data icon.

The observations section of the Quick Look screen highlights questionable parameter programming, device status issues, and atypical episode data.

How to use Quick Look



Displaying episode data or observations

1. If Quick Look is not already displayed, select Quick Look from the Data icon.
2. Highlight an episode, and select [>>] to display specific episode data.
3. Highlight a specific observation. If available, select [>>] to display the selected observation.
4. Select the Lead Performance [>>] button to view lead performance trends.

Quick Look observations

Observations provided by Quick Look are based on an analysis of interrogated data and programmed parameters. Three types of observations are provided: parameter, device status, and episode data.

Parameter observations – Example observations include:

- cautionary messages about the programmed detection and therapy configuration
- pending parameter values
- an ATP therapy that has been disabled by the Smart Mode feature

Device status observations – Example observations include:

- Active Device Status Indicators
- replacement indicator warnings (ERI and EOL)
- a pacing lead impedance of greater than 3000 ohms or less than 200 ohms
- a high voltage lead impedance of greater than 200 ohms or less than 20 ohms
- Patient Alert messages

Episode data observations – Example observations include:

- For each programmed detection zone, the following types of episodes are listed:
  - episodes with unsuccessful therapies, in which more than one therapy was attempted
  - episodes longer than 30 seconds
  - episodes that accelerated to VF
  - monitored episodes
  - episodes where High Rate Timeout occurred
- If more than one episode has occurred for a particular type, the Episode Data Observations section highlights the most recent episode and the total number of episodes of that type.

Using the Patient Alert feature

The Patient Alert monitoring feature is designed to alert the patient if their implanted device meets certain pre-programmed status conditions. The patient should be instructed to notify their physician if an alert sounds. The alerts are programmed to sound at a specific time of the day when the patient or a companion will hear them.

There are three types of alerts:

- High urgency alerts emit a dual, high-low tone.
- Low urgency alerts emit an intermittent on-off tone.
- Test alerts emit a steady tone when the Patient Magnet[1] or programming head is applied to the device to verify that the device alerts are operational and that no alert conditions are met.

Select [Demonstrate Tones...] from the Patient Alert screen to listen to the various alert tones.

High urgency alerts are always on, while others can be set to use either high or low alert tones or programmed completely off. High urgency alerts indicate there is a serious problem with the device that needs urgent attention.

Parameters

* Medtronic nominal setting

PROGRAMMABLE PARAMETERS	
Alert Time – time of day (24 hour) when Patient Alerts are programmed to respond.	
Hour	0, 1, 2, . . ., 8*, . . . 23
Minute	0*, 10, . . ., 50

[1] Refer to the Patient Magnet user manual for more information.

(continued) * Medtronic nominal setting

Lead Impedance Out of Range – indicates that the daily impedance measurement is out of range; could be triggered by a dislodged or improperly connected lead.

Alert Urgency	Low*, High
A. Pacing, V. Pacing Impedance (ohms)	
Enable	On, Off
Minimum Threshold (Less than)	200*, 300, 400, 500,
Maximum Threshold (Greater than)	1000, 1500, 2000, 3000*
Defibrillation and SVC (HVX) defibrillation (ohms)	
Enable	On, Off
Minimum Threshold (Less than)	20*, 30, 40, 50
Maximum Threshold (Greater than)	100, 130, 160, 200*

Low Battery Voltage ERI – indicates that the daily automatic battery voltage measurement has been at or below the 2.62 V (the Elective Replacement Indicator voltage level) on three consecutive days.

Alert Enable - Urgency	Off, On-Low*, On-High
Battery Voltage Threshold (V)	2.62 (ERI) (fixed)

Excessive Charge Time ERI – indicates that the charging period equals or exceeds the Charge Time Threshold.

Alert Enable - Urgency	Off, On-Low*, On-High
Charge Time Threshold (seconds)	16 (fixed)

Number Of Shocks Delivered in an Episode – indicates that the number of shocks delivered in an episode is greater than or equal to the programmed Number of Shocks Threshold.[a]

Alert Enable - Urgency	Off, On-Low*, On-High
Number of Shocks Threshold	1, 2, 3*, 4, 5, 6

All Therapies in a Zone Exhausted for an Episode – indicates that a specific arrhythmic episode was re-detected after all programmed therapies for that type of episode were delivered.

Alert Enable - Urgency	Off, On-Low*, On-High

VF Detection/Therapy Off – indicates that VF detection or more than two VF therapies have been turned off for at least six hours. This alert is programed on in the shipped device and sounds with a High urgency alert tone.[b]

Alert Enable - Urgency	Off, On-High*

(continued) * Medtronic nominal setting

NON-PROGRAMMABLE PARAMETERS

Electrical Reset[c] – indicates that the device has been reset and may require reprogramming. The device immediately sounds a High urgency alert tone that repeats every 20 hours or every 9 hours, depending on the type of electrical reset.[d]

Pacing Mode DOO or VOO – indicates that the DOO or VOO pacing mode is turned on. The device sounds a High urgency alert tone daily at the programmed time.

Active Can Off without SVC – indicates that the Active Can feature is turned off without an SVC lead in place. The device sounds a High urgency alert tone daily at the programmed time.

Charge Circuit Timeout – indicates that a charging period has exceeded the maximum time allowed for circuit charging. The device immediately sounds a High urgency alert tone that repeats every 20 hours.

[a] Note that VF, VT, and/or FVT therapies could be delivered during a single episode (from initial detection until episode termination).

[b] This alert can be turned off if necessary. When the alert is turned on, it does not sound when a magnet is applied, unless VF detection or more than two VF therapies are turned off.

[c] Contact your Medtronic representative if the device has been reset.

[d] In some cases, an electrical reset may disable tachyarrhythmia detection and therapy. If this occurs, the electrical reset patient alert sounds every 9 hours, and the device operates as a simple bradycardia pacing device (in VVI mode, 65 ppm).

Considerations

Review the following information before programming the Patient Alert feature.

Electrical Reset – This alert indicates that the device has been electrically reset. Stored data is cleared, and Programmable parameters may have changed to Reset settings. See Appendix B, "Device Parameters" on page 367 for Reset values. For details about Reset conditions, see “Automatic device status monitoring” on page 304.

Rate Response is suspended – When the Patient Alert sounds, the Rate Response feature is suspended. Any pacing that occurred just before the alert sounds is maintained at the same rate.

Low Battery Alert – This alert is based only on the daily automatic voltage measurements performed by the device. Other voltage measurements do not trigger a Patient Alert.

Multiple alerts – If more than one alert condition has occurred, the most urgent alert is announced at the programmed alert time.

Lead Impedance alerts – These alerts are based on the automatic daily impedance measurements. Impedance measurements recorded during a manual test or high voltage therapy do not trigger a Patient Alert.

- All enabled lead impedance alerts are programmed to the same urgency.
- The atrial lead impedance alert can be enabled if the device is programmed to the VVI or VVIR bradycardia pacing mode.
- A lead impedance alert can be triggered by a dislodged or improperly connected lead.

Condition at the time of alert – The alert condition need not be present when the alert is announced. The alert tone continues to announce each day at the programmed alert time until the device is interrogated.

Alert tone description – The alert tone is designed to be slightly louder than typical living room noise. The alert duration continues for several seconds, up to a maximum of 30 seconds. However, the test alert duration is 20 seconds.

Programming the Alert Time – The programmed Alert Time is based on the device internal clock. Select an Alert Time when the patient can clearly recognize the alert, taking into consideration:

- predictably quiet setting
- daily schedule, e.g., medication routines
- hearing acuity
- presence or absence of companions

Alert frequency – alerts are set to sound at specific intervals depending on the urgency of the alert condition.

Table 11-2. Alert Frequency

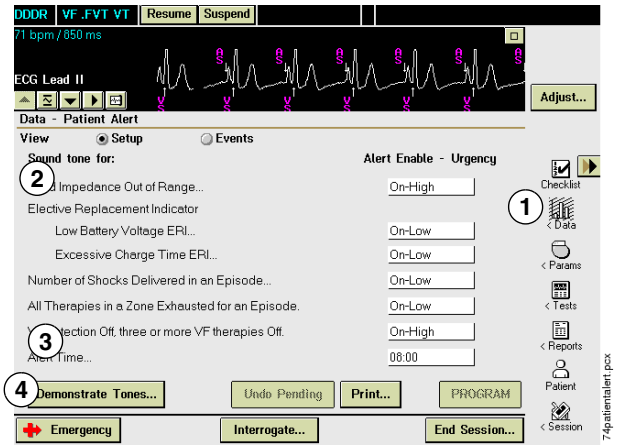
Alerts that sound Immediately	Alerts that sound every 6 hours	Alerts that sound daily at programmed time
Charge Circuit[a] Time-out	VF Detection/ Therapy Off	Pacing Lead Impedance
Electrical Reset[b]		Defibrillation and SVC Lead Impedance
		Low Battery Voltage
		Excessive Charge Time
		Number Of Shocks Delivered in an Episode
		All Therapies in a Zone Exhausted for an Episode
		Active Can Off without SVC
		Pacing Mode DOO or VOO

[a] A Charge Circuit Time-out alert sounds immediately and then every 20 hours. Contact your Medtronic representative if this alert sounds.

[b] An electrical reset alert sounds immediately and then every 20 hours. However, if the electrical reset disables tachyarrhythmia detection and therapy, the alert sounds every 9 hours. Contact your Medtronic representative if an electrical reset alert sounds.

Note: If a programmable Patient Alert is triggered so often that it loses its clinical value, adjust the alert threshold, improve therapy efficacy, or program the alert to off.

How to program the Patient Alert feature



1. Select Data icon > Patient Alert.
2. On the Patient Alert Setup screen, select the alert enable button for the desired alert and set the appropriate thresholds.
3. Select Alert Time... and set the time in 24-hour format.
4. Select [Demonstrate Tones...] and demonstrate the alert tones to the patient. If the patient cannot hear the tones, repeat the demonstration in a quieter environment.

Instructing the patient

The patient should understand the alert tones and what to do if they hear them. Advise the patient

- what time of day the alerts will be announced and that the alert will be announced at the same time each day until the device is interrogated during an office visit
- to contact their physician immediately if they hear tones coming from the device
- that the Alert Time does not adjust for time zone changes
- that the “Test” tone may announce if the device is near a strong electromagnetic field, such as store theft detector. This indicates that the device operation is temporarily impaired[1] and that the patient should move away from the interference source to restore normal operation

The patient should understand what the patient magnet is used for and when to use it. Advise the patient that when the patient magnet is placed over the device, any current alert conditions will be announced.

Demonstrate to the patient how to place the patient magnet over the device to replay the alert tones, and review the patient magnet manual.

[1] For a description of this temporary state, see Table 1-2, “Effects of magnet application on the device,” on page 5.

Note: The patient can use the Patient Magnet Instructions as a folded reference card.

Table 11-3. Responding to Patient Alert tones

Tones	Alert Status	Action
Dual high / low tone	High urgency	**Patient:** Arrange urgent follow-up. **Clinician:** Interrogate device and evaluate alert condition.
Intermittent on / off tone	Low urgency	**Patient:** Arrange follow-up. **Clinician:** Interrogate device and evaluate alert condition.
Steady tone	Test	No Patient Alert condition has occurred (sounds only when in the presence of a strong magnet).

⚠ **Warning:** Be sure the patient understands that they must not carry, store, or leave the magnet positioned over their device.

Viewing the Patient Alert events

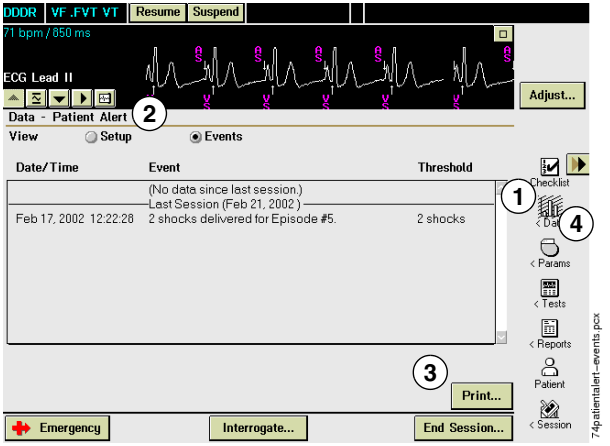
The device stores up to ten Patient Alert events as log entries. To avoid redundant log entries, an entry is recorded only the first time each Patient Alert condition is met.

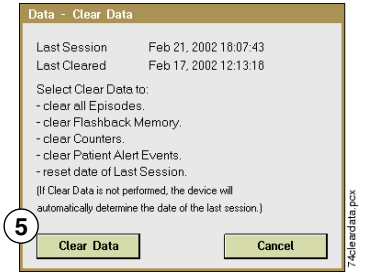
Each log entry includes the date and time of the alert event, a description of the alert event, and the programmable threshold that was exceeded, if applicable. The log is also annotated with the date of the last session.

Interrogating the device resets the audible alert tone but does not clear Patient Alert events from the log. You must manually clear the Patient Alert event log.

Note: The Patient Alert Events screen reports “Open Circuit” if an open circuit interferes with the automatic daily measurement. Check lead connections and lead integrity, and reconnect or replace leads as necessary. See “Measuring lead impedance” on page 316.

How to view the Patient Alert events




Data - Clear Data
Last Session
Feb 21, 2002 18:07:43
Last Cleared
Feb 17, 2002 12:13:18
Select Clear Data to:
- clear all Episodes.
- clear Flashback Memory.
- clear Counters.
- clear Patient Alert Events.
- reset date of Last Session.
(If Clear Data is not performed, the device will automatically determine the date of the last session.)
Clear Data
Cancel
5
74cleardata.pcx

1. Select Data >> Patient Alert.
2. Select [Events].
3. To print the event log, select [Print].

To clear the Event Log data

4. Select Data icon > Clear Data.
5. Select [Clear Data].

   Caution: Do not clear the Patient Alert event log unless you are willing to erase all the stored device and programmer data (counters, episode records, Flashback Memory, and stored EGMs).[a]

   You may wish to print the episode data before clearing it.

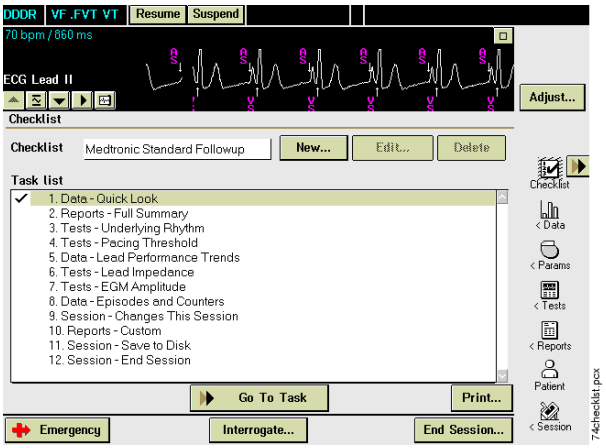
   All data stored in the device and programmer is cleared and the date of last session is reset to the current date.

[a] Clearing the device data does not clear the lead performance or Cardiac Compass trends.

Streamlining follow-ups with Checklist

The Checklist feature provides a method of cataloging tasks performed during routine procedures. Selecting a task from the Checklist displays the programmer screen associated with that task. To display the programmer screen for the next task in the selected checklist, select the double-arrow icon next to the Checklist icon.

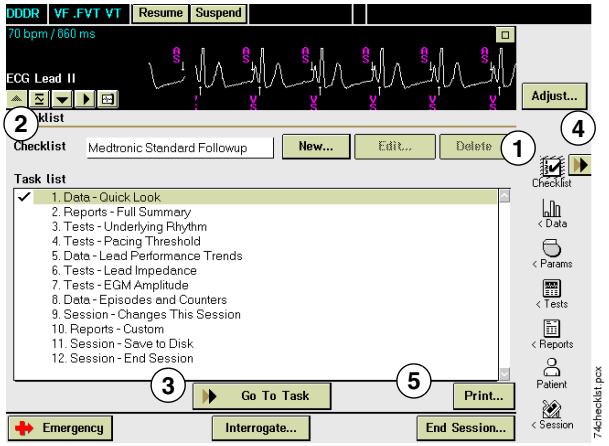
Figure 11-1. Checklist screen



The Checklist screen displays a check mark next to the names of any programmer screens visited during a session. This provides a general indication of the tasks performed during a session.

Two checklists are provided: the Medtronic Standard Implant checklist and the Medtronic Standard Follow-up checklist. In addition to these standard checklists, you can create customized checklists.

How to select and use a checklist



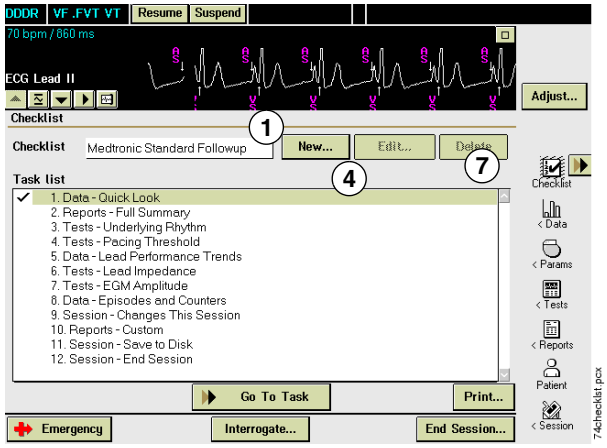
1. Select the Checklist icon and review the tasks displayed for that list.[a]
2. Select the Checklist field to choose a checklist.
3. To start using the checklist, select either [Go To Task] or the double-arrow icon.
4. Perform the selected task and continue to the next task by selecting the double-arrow icon.

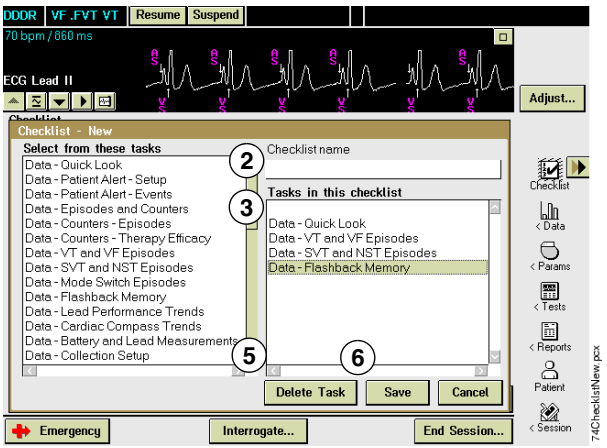
   To perform a task out of order or repeat a task from the selected Checklist, select the Checklist icon, select the task, then choose [Go To task] or the double-arrow icon.[b]
5. Select [Print] from the Checklist screen.

[a] When starting a new session, the checklist used during the last programming session becomes the active checklist.

[b] You can select a task whether it is marked with a checkmark or not. When you select the last task in a checklist, the double-arrow icon and the [Go To Task] button are disabled. To re-enable these functions, select a different task or a checklist from the Checklist screen.

How to create, edit, and delete a checklist





To create or edit a checklist

1. To create a new checklist, select [New] from the checklist screen.

   To edit a checklist, select an existing checklist to edit.[a]
2. Enter a name for the list or modify the existing name (if desired).
3. Assemble a new list with up to 100 tasks by tapping the name of a task in the “Select from these tasks” box. The selected task appears in the new checklist box. (Tasks can be added more than once to a new checklist.)
4. Edit a checklist by selecting it, then selecting [Edit].[a]

   To change the order of tasks, highlight the task in the checklist that should precede the task you are moving.

   Tap the new task to be inserted, and it appears below the highlighted task.
5. Delete a task by selecting it, then selecting [Delete Task].
6. Select [Save] to save the new or edited checklist.

To delete a checklist

7. Select the checklist to be deleted from the checklist menu, and select [Delete].

[a] The Medtronic Standard Follow-up and Medtronic Standard Implant checklists cannot be edited or deleted, so the [Edit...] and [Delete] buttons are unavailable when these checklists are selected.

Key terms

Checklist – interactive display of the programmer screens in a standard order, to help operate the programmer more efficiently. Clinicians can set up their own checklists or use a Medtronic standard checklist supplied with the programmer.

electrical reset – automatic device operation to recover from a disruption in device memory and control circuitry. Programmed parameters may be set to electrical reset values.[1] This operation triggers a device status indicator and an automatic Patient Alert tone.

Observations – programmer messages in the Quick Look screen that identify possible issues of concern in the programming or status of the device.

Patient Alert monitoring system – audible alerts that notify the patient when any of the programmable alert conditions have occurred so that the patient can schedule an appointment.

QuickLink software design – navigation feature that provides easy, direct access between related programmer screens.

Quick Look software display – programmer screen that provides a summary of device status, notable events since the last interrogation, counters, and programming observations.

[1] See Appendix B, "Device Parameters" on page 367 for reset settings.

Setting up and viewing collected data

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A summary of data collection

The device collects and stores various types of data and provides a range of diagnostic tools to manage the care of your patient.[1] The table below summarizes the data and diagnostic tools, which are described in detail in the rest of the chapter.

Quick Look	Summarizes patient and system information since last session that may merit further investigation (see page 251)
Patient Alert	Logs up to ten Patient Alert events (see page 253)
Episodes and counters	Counter data: ▪ Episode counts for VF, FVT, VT, AFib/AFlutter, Sinus Tach, Other 1:1 SVT, NST, Mode Switch episodes ▪ Percent pacing and VRS pacing counts ▪ PVC counts ▪ Therapy efficacy counts for delivered, successful, unsuccessful, intervention, and total aborted therapies Episode data: ▪ Interval plot, EGM strip, and episode text ▪ 150 VF, FVT, and VT episodes 50 SVT and NST episodes 53 mode switch episodes ▪ Flashback memory – 2000 A-A and V-V intervals prior to last interrogation, most recent VF episode, and most recent VT episode
Cardiac Compass trends	Graphical report showing up to 14 months of episodes and therapies, ventricular rates, percent pacing, and patient activity (see page 294)
Battery and lead measurements	Battery voltage, last capacitor formation, last charge, lead impedance, last high voltage therapy, and sensing integrity information (see page 290)
Lead performance trends	View lead impedance and EGM amplitude graphs for up to 80 weeks (accessed via Quick Look, Battery and Lead Measurements, and Lead Impedance Test screens) (see page 290)

[1] If three question marks appear in place of device data, this indicates that the data is invalid or unavailable.

Setting up data collection

Although data collection is automatic, some parameters related to data collection are selectable. The device allows you to

- select the EGM source and amplifier range
- specify EGM storage before the start of a tachycardia or during capacitor charging
- set the device date and time
- turn on the Holter Telemetry feature
- define the Premature Event Threshold

For details about data collection parameters, see page 269.

Parameters

* Medtronic nominal setting

EGM Source – Electrodes between which the device records the EGM signal for each EGM channel.	EGM 1 (A or V) Can to HVB Can to Vring Can to Aring Vtip to HVB Vtip to Vring Atip to Vring Atip to Aring* Can to HVX[a] HVB to HVX[a]	EGM 2 (V) Can to HVB Can to Vring Vtip to HVB Vtip to Vring* Can to HVX[a] HVB to HVX[a]
EGM Range (± mV) – EGM amplifier signal range. Smaller settings result in higher resolution telemetered and stored EGM waveforms.	2, 4, 8*, 16	2, 4, 8*, 16
Store this channel? – Selects whether EGM 1 is stored in addition to EGM 2.	Yes* or No	
Store EGM during charging? – Specifies EGM storage during charging for automatic cardioversion and defibrillation therapies.	Yes* or No	

(continued)	* Medtronic nominal setting
Store EGM before tachycardia starts? – Specifies EGM storage for 20 seconds of EGM prior to the start of an episode. EGM data from both channels is stored if EGM 1 storage is enabled.	Yes or No*
Device Date/Time – Sets the date and time of the device internal clock.	
Holter Telemetry (hours) – Transmits EGM and Marker Channel data continuously for a selectable number of hours, regardless of whether the programming head is positioned over the device.	Off*, 0.5, 1, 2, 4, 8, 16, 24, 36, 46
Premature Event Threshold (%) – Specifies the percentage of the average intrinsic rate used to classify a sensed event as premature.	56, 59, 62, 66, 69*, . . ., 84, 88, 91, 94, 97

[a] An SVC lead must be present for this configuration.

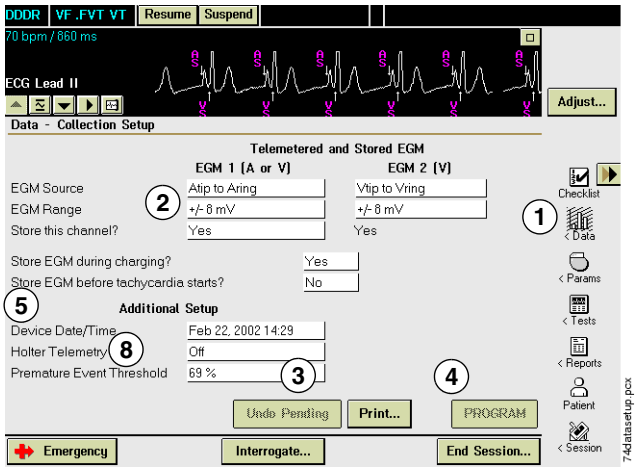
Considerations

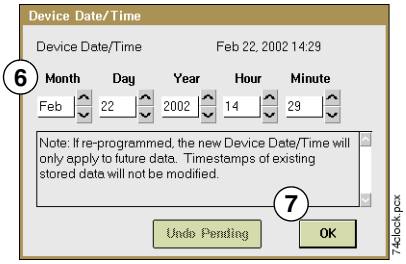
Review these programming considerations before programming data collection parameters.

Effect on device longevity – Using some EGM storage features decreases the longevity of the device. To maximize longevity, turn off EGM channel 1 storage, storage before the start of a tachycardia, and storage during charging. Using the Holter Telemetry also decreases the longevity of the device.

Memory conservation – To conserve as much EGM storage capacity as possible for additional episodes, consider turning off EGM storage during charging and before the start of a tachycardia.

How to set up data collection





Set data collection

1. Select Data > Collection Setup.
2. Set the EGM Source, EGM Range, and EGM storage options.
3. Select a percentage for the Premature Event Threshold.
4. Select [Program].

Set the device clock

5. Select Device Date/Time.
6. Use the up and down arrow buttons to select hour, minute, and date settings. Use 24-hour notation: midnight is 00:00; noon is 12:00.
7. Select [OK] and select [PROGRAM].

Set Holter Telemetry

8. Select Holter Telemetry and choose a value.
9. Select [PROGRAM].

Details about data collection parameters

EGM source

The device has two programmable EGM channels (EGM 1 and EGM 2) that define the lead pathways used for real-time (telemetered) and stored EGM.

- EGM 1 and EGM 2 channels are displayed in real-time.
- EGM 1 storage can be programmed on or off and is available for atrial or ventricular lead and high voltage pathways.
- EGM 2 storage is always on and is available for only ventricular and high voltage pathways.

With EGM 1 storage on, the device stores up to 14 minutes of dual channel VT/VF EGM and up to 2 minutes of dual channel SVT/NST EGM, along with the associated intervals and markers.

With EGM 1 storage off, the device stores up to 23.5 minutes of single channel VT/VF EGM and up to 3.6 minutes of single channel SVT/NST EGM, along with the associated intervals and markers.

Note: The cardiac interval measurements of the ICD are always based on the signals sensed through the tip and ring electrodes of the ventricular lead. Therefore, tachyarrhythmia interval criteria, synchronization, and therapy are not affected by your selection of EGM sources.

Table 12-1. EGM Source Options

	EGM 1	**EGM 2**
Near-Field	Atip to Aring (nominal) Vtip to Vring	Vtip to Vring (nominal)
Far-Field	Can to HVB[a] Can to Vring Can to Aring Vtip to HVB[b] Atip to Vring HVB to HVX[c] Can to HVX[c]	Can to HVB[a] Can to Vring Vtip to HVB[b] Can to HVX[c] HVB to HVX[c]

[a] HVB = high voltage coil

[b] Far-field if using true bipolar lead, near-field if using integrated bipolar lead.

[c] HVX = SVC electrode

Leadless ECG signal – If a supplementary high voltage electrode is placed in the SVC, the device provides the Leadless ECG signal through the Can to SVC (HVX).

This EGM source approximates an ECG signal, displaying both P- and R-waves.

Figure 12-1. An example of Leadless ECG (CAN-HVX EGM)

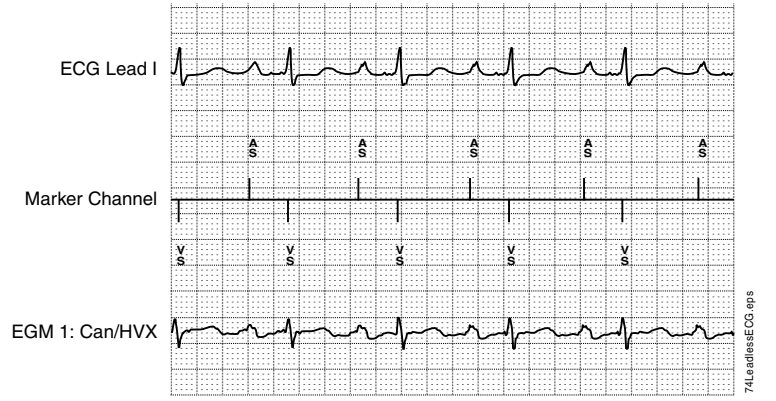
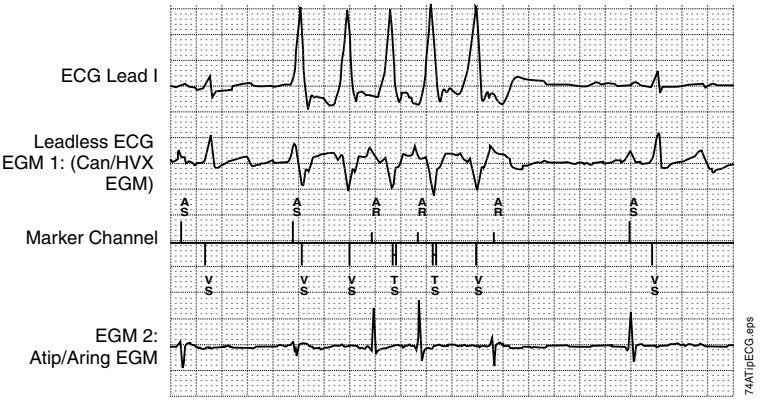


Figure 12-2. An example of Leadless ECG (CAN-HVX EGM) during a short run of VT



Premature event threshold

The premature event threshold is the interval threshold that defines a premature event, such as a premature ventricular contraction (PVC). A cardiac beat is classified as premature if its interval is less than the programmed premature event threshold. The event threshold is a percentage of the most recent four intervals. For more information about PVCs, see “Detecting and preventing pacemaker-mediated tachycardia” on page 189.

Device clock

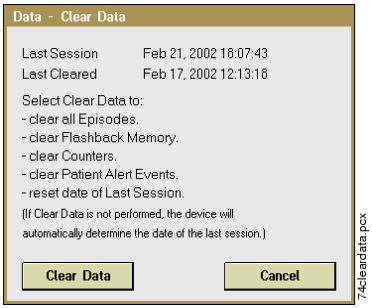
The device uses an internal clock, separate from the programmer clock, to mark the date and time of significant events throughout the life of the device. It stores these date and time stamps in memory along with other event data.

The device clock should be set during the implant procedure and under other circumstances such as if the patient changes time zones for a length of time.

Holter Telemetry

The Holter Telemetry feature transmits EGM and Marker Channel data continuously for a selectable number of hours, regardless of whether the programming head is positioned over the device. The EGM and Marker Channel data transmitted using Holter Telemetry is not stored in device memory. Additional equipment is required to record the data. Please contact your Medtronic representative for more information about the use of the Holter Telemetry.

How to clear collected data


Data - Clear Data
Last Session Feb 21, 2002 18:07:43
Last Cleared Feb 17, 2002 12:13:18
Select Clear Data to:
- clear all Episodes.
- clear Flashback Memory.
- clear Counters.
- clear Patient Alert Events.
- reset date of Last Session.
(If Clear Data is not performed, the device will automatically determine the date of the last session.)
Clear Data
Cancel
74cleardata.pcx

1. Select the Data icon.
2. Choose [Clear Data...].
3. Select [Clear Data] to clear data in device and programmer memory and reset the Last Session date.

   Note: Selecting [Clear Data] does not clear lead performance or Cardiac Compass trends. Cleared information includes counters, episode records, Flashback Memory, Patient Alert event log.

Collecting lead performance data

The device collects electrical data about the lead system that allows you to assess lead integrity over the time between patient sessions. This data is collected automatically (with no setup required) and can be viewed or printed during a patient session.

Daily lead impedance and EGM amplitude measurements

The device automatically measures lead impedances and EGM amplitudes each day starting at 3:00 am.[1]

Lead impedances – The device measures the atrial and ventricular pacing and high voltage lead impedances using sub-threshold electrical pulses that are synchronized to sensed or paced events but do not capture the heart. If the patient is experiencing a tachyarrhythmia episode (or undergoing programmer-initiated inductions, therapies, or tests) during a scheduled measurement, the device defers the measurement until the next day and logs the value as “not taken.”

EGM amplitudes – Starting at 3:00 am, the device attempts to measure the EGM amplitudes for five normal intrinsic atrial and ventricular sensed events. When a complete set of five atrial and five ventricular sensed events has been measured, the device calculates the median atrial and ventricular amplitudes in the set. If no sensed events can be measured, the device defers the measurement until the next day and logs the value as “not taken.”

The lead impedance and EGM amplitude values are stored in device memory and may be viewed during a patient session via lead performance trends and various displays and reports. Lead impedance values are also used by the Patient Alert feature to notify the patient in the event that an impedance value is out of range.

[1] Based on the internal device clock.

Sensing integrity counter

A sensing integrity counter records the number of short ventricular intervals that occur between patient sessions[1]. The sensing integrity counter records any sensed ventricular event with a V-V interval shorter than 140 ms (unless the previous ventricular event was paced) since the last session.

Note: If the number of short intervals displayed exceeds 300, the programmer displays a Quick Look observation.

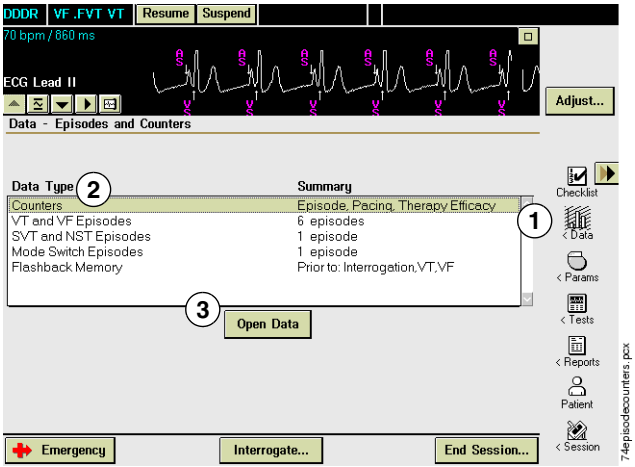
A large number of short ventricular intervals may indicate situations like oversensing, lead fracture, or a loose set screw.

Viewing the episode and therapy efficacy counters

The device continuously stores significant events such as detected episodes and therapy deliveries as counter data in memory. There are two types of counters: Episode and Therapy Efficacy. The programmer allows you to view the counters on the screen and print the counter data out in several ways.

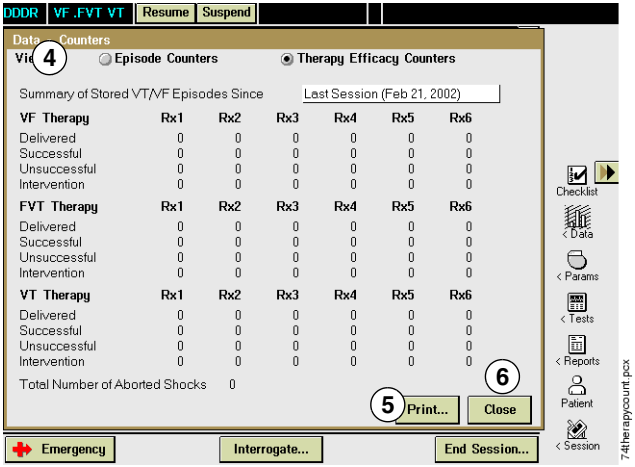
[1] Defined as intervals since stored data was cleared or the last session ended.

How to view and print counter data



Interrogate the device if you have not already done so.

1. Select Data > Episodes and Counters.
2. Highlight Counters in the Data Type list.
3. Select [Open Data].



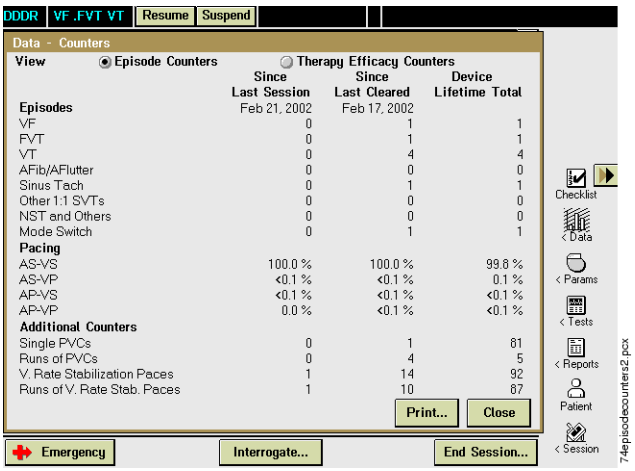
4. Select either Episode Counters or Therapy Efficacy Counters.
5. Select [Print] to print the displayed counters.
6. Select [Close] to return to the Episodes and Counters screen.

Details about the episode and therapy efficacy counters

Episode Counters

The device maintains cumulative counters of the number of tachyarrhythmias, supraventricular tachycardias (SVT), and non-sustained episodes (NST) since the last patient session, since data was last cleared, and for the lifetime of the device.

Figure 12-3. Episode Counters



VF, FVT, and VT – report the number of episodes of each arrhythmia, based on the initial detection.

Atrial Fib/Atrial Flutter, Sinus Tach, and Other 1:1 SVTs – reports the number of episodes where a PR Logic Criterion was met, causing detection and therapy to be withheld.

NST and Others – reports the number of non-sustained tachyarrhythmias and other high rate episodes.

Mode Switch – reports episodes where Mode Switch switched the pacing mode to DDIR during an atrial tachyarrhythmia.

% Pacing[1] **–** reports the patient's A-V conduction history (atrial sense with ventricular sense, atrial sense with ventricular pace, etc.) as percentage of the total time during the reporting period. These counters do not count refractory senses, VRS pacing pulses, or events immediately preceded by Charge End. Due to rounding and dissociation, percentages might not add to 100%.

Single PVCs[1] **–** reports premature events with intervals less than the Premature Event Threshold**.**

Runs of PVCs[1] **–** reports "runs" of PVCs in which two, three, or four consecutive ventricular events are premature.

V. Rate Stabilization Paces[1] **–** reports VRS pacing pulses (VRS escape interval timeouts).

Runs of V. Rate Stab. Paces[1] **–** reports "runs" of VRS pacing pulses in which one or more consecutive ventricular events are VRS pacing pulses.

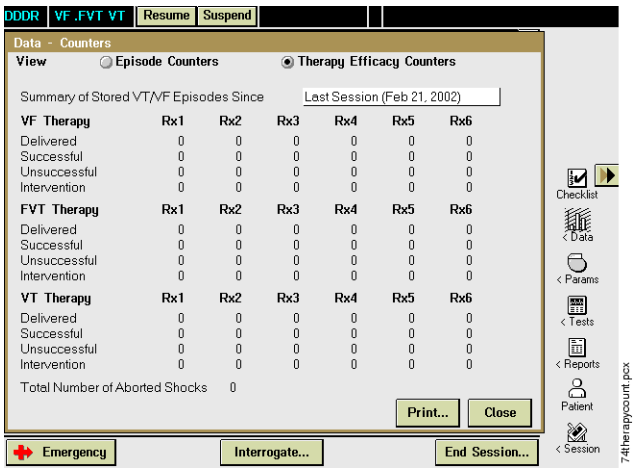
[1] These counters do not increment during a detected tachyarrhythmia episode.

Therapy counters

Therapy counters include delivered, successful, unsuccessful, intervention, and total aborted high voltage therapies. The intervention counter indicates the number of times that therapy success could not be determined because of physician intervention such as a manual therapy delivery.

The saved episode information is provided since the last patient session, since data was last cleared, and for the lifetime of the device.

Figure 12-4. Therapy efficacy counters

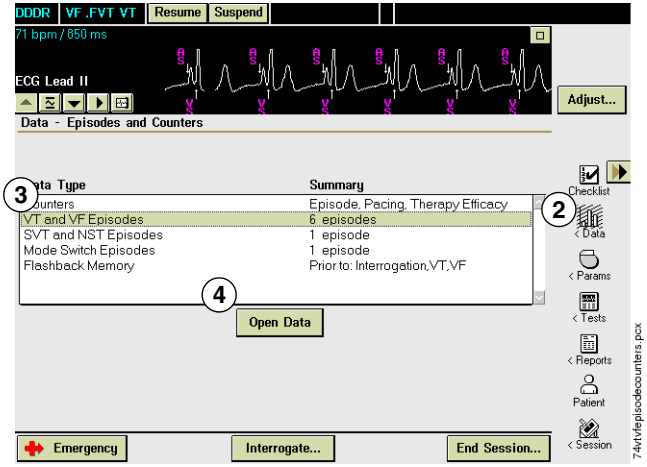

DDDR
VF .FVT VT
Resume
Suspend
Data - Counters
View
Episode Counters
Therapy Efficacy Counters
Summary of Stored VT/VF Episodes Since
Last Session (Feb 21, 2002)
VF Therapy Rx1 Rx2 Rx3 Rx4 Rx5 Rx6
Delivered 0 0 0 0 0 0
Successful 0 0 0 0 0 0
Unsuccessful 0 0 0 0 0 0
Intervention 0 0 0 0 0 0
FVT Therapy Rx1 Rx2 Rx3 Rx4 Rx5 Rx6
Delivered 0 0 0 0 0 0
Successful 0 0 0 0 0 0
Unsuccessful 0 0 0 0 0 0
Intervention 0 0 0 0 0 0
VT Therapy Rx1 Rx2 Rx3 Rx4 Rx5 Rx6
Delivered 0 0 0 0 0 0
Successful 0 0 0 0 0 0
Unsuccessful 0 0 0 0 0 0
Intervention 0 0 0 0 0 0
Total Number of Aborted Shocks 0
Print...
Close
Emergency
Interrogate...
End Session...
Checklist
< Data
< Params
< Tests
< Reports
Patient
< Session
74therapycount.pcx

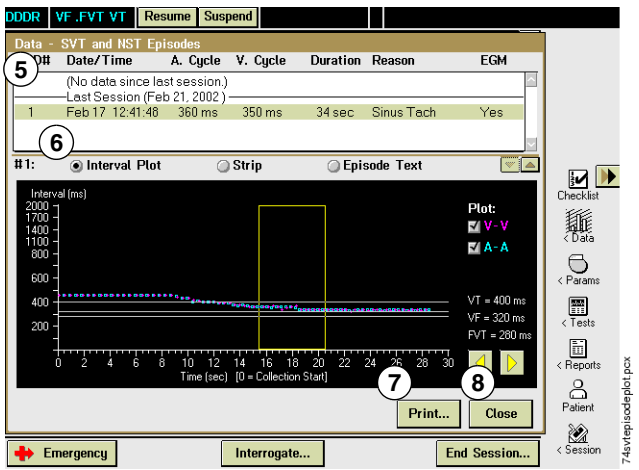
Viewing episode data

The Episode Data recorded by the device is summarized below.

Episode Logs (see page 282)	Summary episode information for up to: 150 VF, FVT, and VT episodes, 50 SVT and NST (non-sustained) episodes, and 53 mode switch episodes
Episode Records (see page 283)	Detailed episode data for VF, FVT, and VT episodes (and some SVT and NST episodes): **Interval Plot** V-V and A-A intervals plotted versus time, point of detection, and therapy delivery **EGM Strip** 1 or 2 channels of stored EGM, Interval data, Marker Channel, and Decision Channel **Episode Text** Episode summary in textual format
Flashback Memory (see page 288)	Plots of up to 2000 intervals (containing both A-A and V-V): prior to last interrogation prior to most recent VF episode prior to most recent VT episode

How to view episode data





1. Interrogate the device if you have not already done so.
2. Select Data > Episodes and Counters.
3. Highlight VT and VF Episodes or SVT and NST Episodes or Mode Switch Episodes in the Data Type list.
4. Select [Open Data].
5. Select an episode from the episode log. The shaded row indicates which episode is displayed.
6. Choose [Interval Plot], [Strip], or [Episode Text] to display more details[a].
7. To print a report based on the displayed episode information, select [Print] and choose from the available print options.
8. Select [Close] to display the Episodes and Counters screen.

[a] Mode Switch episodes are only displayed in the Episode Log area. Episode record information is not stored.

Details about episode data

Episode log

Episode log storage capacities are shown in Table 12-2. For each type of episode, when the log capacity is filled, newly detected episode information overwrites the oldest episode information in the log.

Note: Use the scroll buttons on the right side of the log area to scroll through the list of stored episodes.

Table 12-2. Episode Log Capacity

Episode Log	Storage Capacity
VF, VT, and FVT	Up to 150 of the most recent episodes
SVT and NST	Up to 50 of the most recent episodes
Mode Switch	Up to 53 episodes, including the 50 most recent, the first, the fastest rate, and the longest (no graphs)

Figure 12-5. Example VT and VF episode log

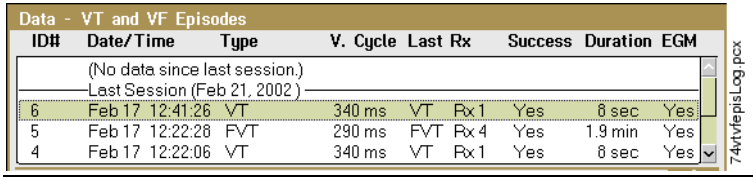

Data - VT and VF Episodes
ID# Date/Time Type V. Cycle Last Rx Success Duration EGM
(No data since last session.)
Last Session (Feb 21, 2002)
6 Feb 17 12:41:26 VT 340 ms VT Rx 1 Yes 8 sec Yes
5 Feb 17 12:22:28 FVT 290 ms FVT Rx 4 Yes 1.9 min Yes
4 Feb 17 12:22:06 VT 340 ms VT Rx 1 Yes 8 sec Yes
74vtvfepisLog.pcx

Figure 12-6. Example SVT and NST episode log

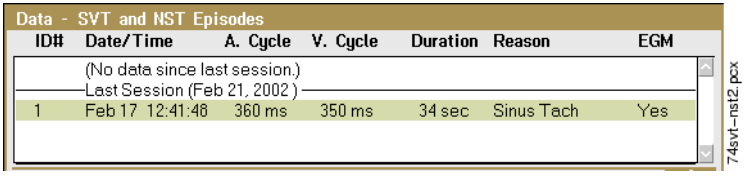
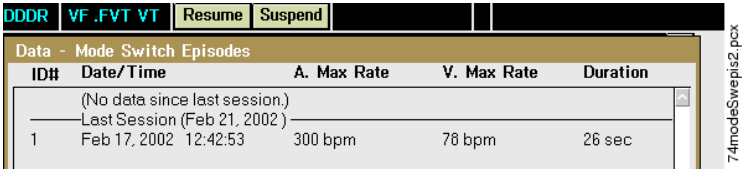

Data - SVT and NST Episodes
ID# Date/Time A. Cycle V. Cycle Duration Reason EGM
(No data since last session.)
Last Session (Feb 21, 2002)
1 Feb 17 12:41:48 360 ms 350 ms 34 sec Sinus Tach Yes
74svt-nst2.pcx

Figure 12-7. Example Mode Switch Episode Log


DDDR
VF .FVT VT
Resume
Suspend
Data - Mode Switch Episodes
ID# Date/Time A. Max Rate V. Max Rate Duration
(No data since last session.)
Last Session (Feb 21, 2002)
1 Feb 17, 2002 12:42:53 300 bpm 78 bpm 26 sec
74modeSwepis2.pcx

Episode records

The episode record displays detailed information about the episode selected in the log. Episode records are available only for VT, VF, FVT, SVT, and some NSTs. For a particular episode, you can display the episode record data in one of the following formats:

- an interval plot
- a strip chart of the stored EGM
- a text summary

Note: Episode data is not fully updated in device memory until the episode terminates.

Episode records are stored in the order the episodes occur, with new data overwriting the oldest data when the storage capacity is filled.

Storing SVT and NST episodes – SVT and NST episodes are high-rate episodes that do not fulfill VF, VT, or FVT episode detection. Generally, episode record data are stored only for SVT episodes.

An SVT/NST event is counted when the ventricular interval is less than the VT Interval,[1] and the count resets to zero when an interval is greater than or equal to the VT Interval.

This counter differs from the VT event counter in that it advances for intervals in the VF and FVT zones, and it does not reset for intervals rejected by the VT Stability criterion.

If an episode terminates before the SVT/NST counter reaches the VT NID,[1] the episode is classified as non-sustained, and episode data are not stored.

Episode data are stored if the SVT/NST counter reaches the VT NID, but VF/VT/FVT detection does not occur. Usually this means the episode was rejected by the PR Logic or Stability criteria; however, EGM may be stored for certain NSTs (such as when the VT NID is programmed lower than the VF NID).

[1] VF Interval and VF NID, if VT detection is off.

Interval Plot

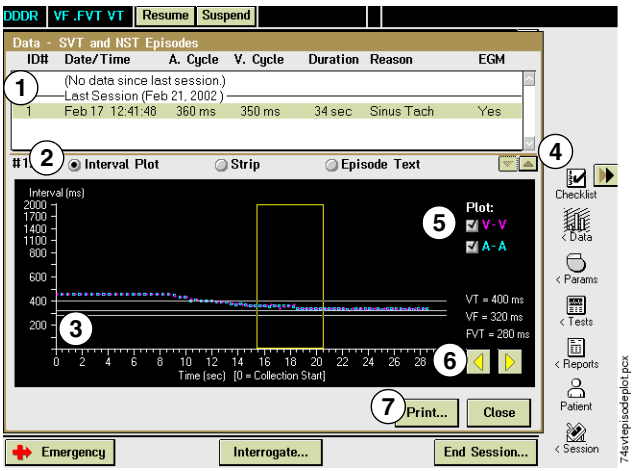
When you first select an episode from an episode log, the programmer displays a graph which plots the V-V and A-A intervals versus time, and indicates:

- the programmed detection intervals
- point of detection
- point of therapy delivery

The time value for each interval is plotted along the x-axis; the interval value is plotted in milliseconds along the y-axis. In plots of VF, VT, and FVT episodes, zero marks the episode detection. In plots of SVT episodes, zero marks the start of data collection.

Note: If the device truncates data storage during an episode, the programmer displays time labels following the truncation on the interval plot as asterisks. See “EGM Strip memory” on page 286.

How to view an Interval Plot



1. Select an episode from the log. The shaded row indicates which episode is displayed.
2. Select [Interval Plot].
3. Compare the recorded intervals to the programmed detection intervals.
4. Select the Maximize/Minimize buttons to adjust the size of the graph if desired.
5. Select the interval types to display.
6. Move the magnification window with the arrow buttons to select an area for the EGM Strip display.
7. Select [Print] to print the displayed information.

EGM Strip

When the VT or VF interval count reaches three, the device starts storing EGM data. If pre-onset EGM storage is on, the device stores up to 20 seconds of EGM data from before detection of the VT, FVT, or VF episode. If pre-onset EGM storage is off, the device stores only interval data (up to 12 ventricular intervals) from before the onset of the episode.

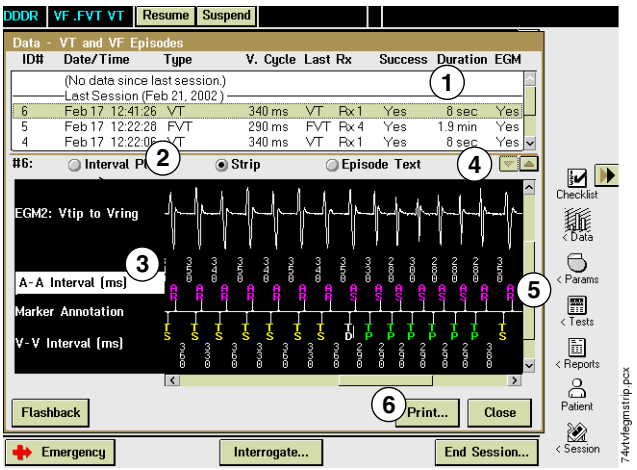
Note: To view all of the EGM strip data, use the scroll bars on the right side and bottom of the screen.

SVT and NST episodes – The device stores up to 20 seconds of EGM data for each SVT episode. Generally, EGM strips are not stored for NST episodes.

Atrial interval display options – The EGM Strip screen provides four options for displaying atrial intervals. These include A-A intervals, A-V intervals, V-A intervals, and A-V / V-V percentage values.

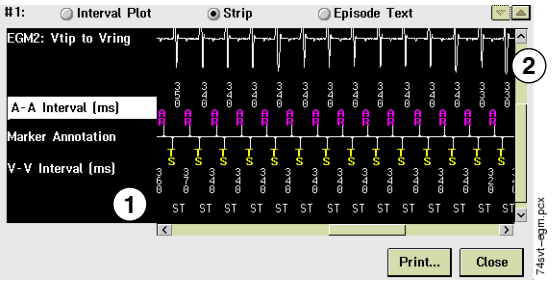
Decision Channel annotations – Decision Channel annotations appear below the ventricular intervals as appropriate (see Figure 12-8).

How to view an EGM Strip



1. Select an episode from the log; note the EGM column indicating if an EGM strip is available for that episode.
2. Select [Strip].
3. Select the interval display area to select an interval to display.
4. Select the Maximize/Minimize buttons to adjust size of display if desired.
5. Scroll display with scroll bars.
6. Select [Print] to print the displayed information.

Figure 12-8. EGM Strip Screen (SVT episode)



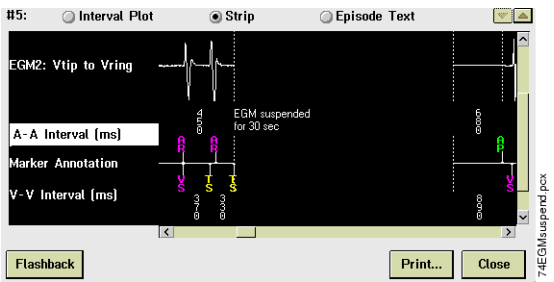
1 Decision channel shows sinus tach criterion satisfied.

2 End of EGM strip storage.

EGM Strip memory – Conserving storage space for EGM information is automatically performed by

- truncating EGM storage for single, unusually long episodes, so that no more than three minutes of VT/FVT/VF EGM is stored for a single episode and 20 seconds stored for each SVT/NST episode.
- recording up to 25 seconds of EGM between therapy deliveries or between the last therapy delivery and episode termination. If more than 25 seconds elapse between these events, 5 seconds of EGM is stored after the therapy before recording is suspended, then 20 seconds of EGM is stored before the next therapy (or episode termination). The amount of time that recording was suspended is displayed (see Figure 12-9).

Figure 12-9. Suspended EGM recording

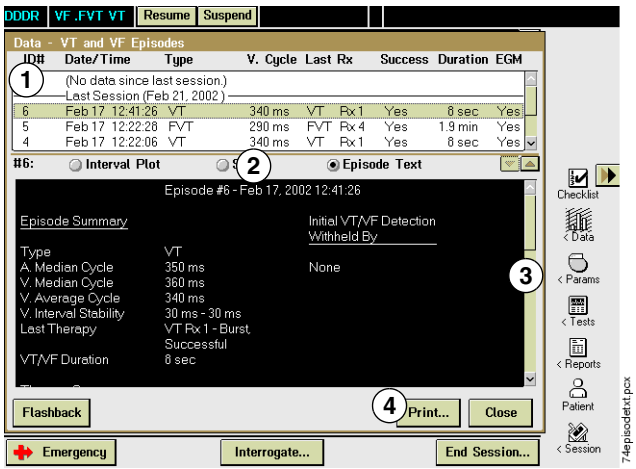


Episode Text

The Episode Text screen provides a summary of the episode, including the therapy sequence (VF, FVT, and VT episodes only), parameter settings, and notation of SVT criterion met.

To view all of the episode text, use the scroll bar on the right side of the screen.

How to display the episode text information



1. Select an episode from the log. The shaded row indicates which episode is displayed.
2. Select [Episode Text].
3. Scroll display with scroll bar.
4. Select [Print] to print the displayed information.

Viewing Flashback Memory

Flashback Memory is available from the episode record screens. This feature allows you to analyze a patient's heart rate leading up to a VF or VT episode and compare the pre-VF and pre-VT rhythms to the patient's normal sinus rhythm and to other episodes.

Flashback Memory automatically records up to a total of 6000 intervals in the following combination:

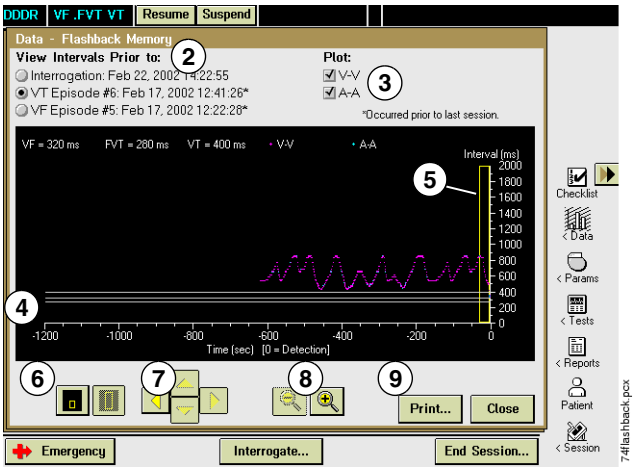
- prior to the most recent VF episode (up to 2000, A-A and V-V combined)
- prior to the most recent VT episode (up to 2000, A-A and V-V combined)
- prior to the most recent interrogation (up to 2000, A-A and V-V combined)

Flashback Memory is not programmable and is always turned on.

Note: If FVT Detection is on while recording, it records an FVT episode as either a VT episode (if detected via the VT zone) or a VF episode (if detected via the VF zone).

Interval storage is suspended when a VF, FVT, or VT episode is in progress.

How to view the Flashback Memory



1. Select the Flashback Memory data type from the Episodes and Counters screen[a] and then select [Open Data].
2. Select an episode to display.
3. Select the interval plots to display.
4. View programmed detection intervals, shown as horizontal lines in graph area.
5. Note the zoom window.
6. Resize zoom window if desired.
7. Move zoom window if desired.
8. Magnify zoom window if desired.
9. Select [Print] to print displayed information.

[a] You can also display the Flashback Memory screen by selecting [Flashback] from the most recent VT, VF, or FVT record detail screens.

Viewing battery and lead status data

The device automatically and continuously monitors its battery and lead status throughout the life of the device. After you interrogate the device, the programmer allows you to display and print the following data:

- current battery voltage
- most recent capacitor formation
- most recent capacitor charge
- sensing integrity counter data
- most recent lead impedance
- most recent EGM amplitudes
- most recent high voltage therapy

The device measures the battery voltage when telemetry is initiated or a magnet is applied, when a lead impedance test is performed, and as part of the automatic measurements at 3:00 am daily.[1]

The values displayed may be either actual measurements or calculations based on actual measurements. If the device has been reset, certain measurements may not be available, and the message “No measurement since reset” is displayed until a new measurement is taken.

For information on lead impedance measurements and the sensing integrity counter, see page 275.

For information about optimizing capacitor charge time and device longevity, see page 203.

[1] Based on the device clock, see “Device clock” on page 272.

Replacement indicators

If the battery voltage is less than or equal to the Elective Replacement Indicator (ERI) value, the programmer displays

- a message recommending that you replace the device
- an ERI symbol on the Quick Look and the Battery and Lead Measurements screen
- a date on the Quick Look and Battery and Lead Measurements screen indicating when the battery reached ERI

When the device reaches ERI, contact your Medtronic representative and schedule an appointment to replace the device.

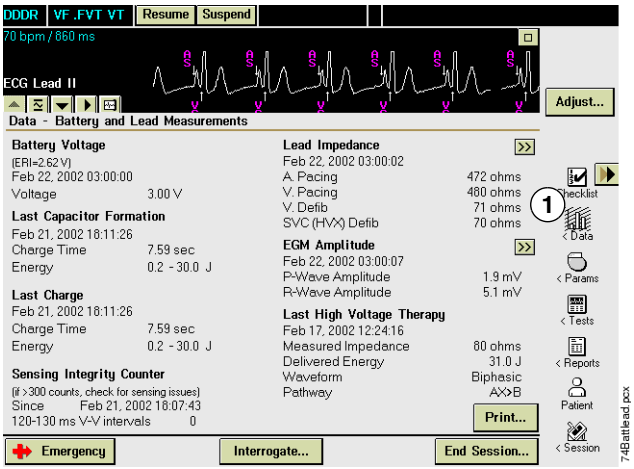
If three months have passed since the device reached ERI, the device is at End of Life (EOL)[1] and the programmer displays

- a message recommending immediate replacement of the device
- an EOL symbol on the Quick Look and Battery and Lead Measurements screen

⚠ **Warning:** If the programmer indicates that the device is at EOL, replace the device immediately.

[1] EOL may be indicated before the end of three months if actual battery usage exceeds the post-ERI operating conditions. See “Post-ERI conditions” on page 9.

How to view battery and lead status data



Interrogate the device if you have not already done so.

1. Select Data > Battery and Lead Measurements.

Viewing lead performance trends

The automatic daily lead impedance and EGM amplitude measurements (see page 274) are used to generate lead performance graphs based on up to 80 weeks of measurements.[1]

A separate graph is provided for each of the following measurements:

- atrial pacing lead impedance
- ventricular pacing lead impedance
- defibrillation lead impedance
- SVC lead (if used) impedance
- P-wave EGM amplitude
- R-wave EGM amplitude

Each graph displays values above the graph area for the measurement at implant, the last measured value, the highest value collected for the measurement, and the lowest value collected for the measurement.

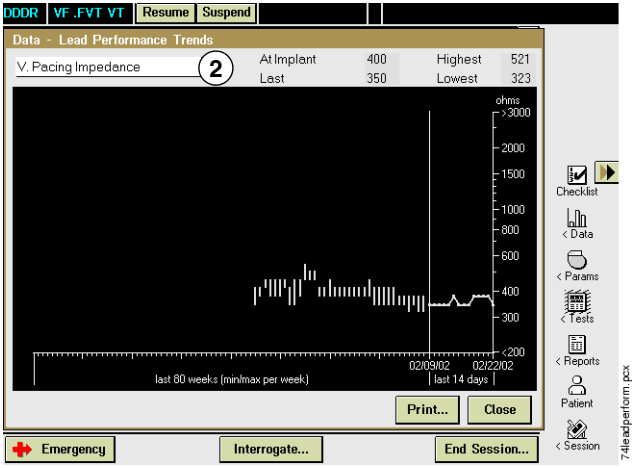
The impedance information that is graphed includes:

[1] The graphs are based on the weekly minimum and maximum impedance values for up to 80 weeks and the most recent 14 days of daily measurements.

- the weekly minimum and maximum values for up to 80 weeks
- the last 14 days of measured values

Every seventh day after the device is implanted, weekly minimum and maximum measurements are recorded, and the lifetime minimum and maximum values are updated.

How to view lead performance trend graphs



1. Select the [>>] button next to the lead impedance or EGM amplitude data displayed on the Battery and Lead Measurements screen, Quick Look screen, Lead Impedance Test screen, or EGM Amplitude Test.
2. To change to another graph, select a graph from the pull-down menu in the top left corner of graph.

   The previous 14 days of recorded data is displayed in a series of daily actual impedance values. Historical data is displayed as weekly minimum and maximum values.

Using Cardiac Compass to view long term clinical trends

The Cardiac Compass report provides up to 14 months of clinically significant data including arrhythmia episodes, therapies delivered, physical activity, heart rate, and bradycardia pacing activity (see Figure 12-10). The report can be useful, for example, in correlating changes in data trends to changes in programmed parameters, drug regimen, or patient condition.

The Cardiac Compass report provides an overall view based on the following daily checks or measurements:

- programming and interrogation annotations
- VT/VF episodes
- indication of a cardioversion or defibrillation therapy delivered
- ventricular rate during VF, FVT, VT episodes
- number of NST episodes per day
- total time in AT or AF
- ventricular rate during AT or AF
- percent atrial and ventricular pacing
- average day and night ventricular rate
- overall patient activity
- heart rate variability

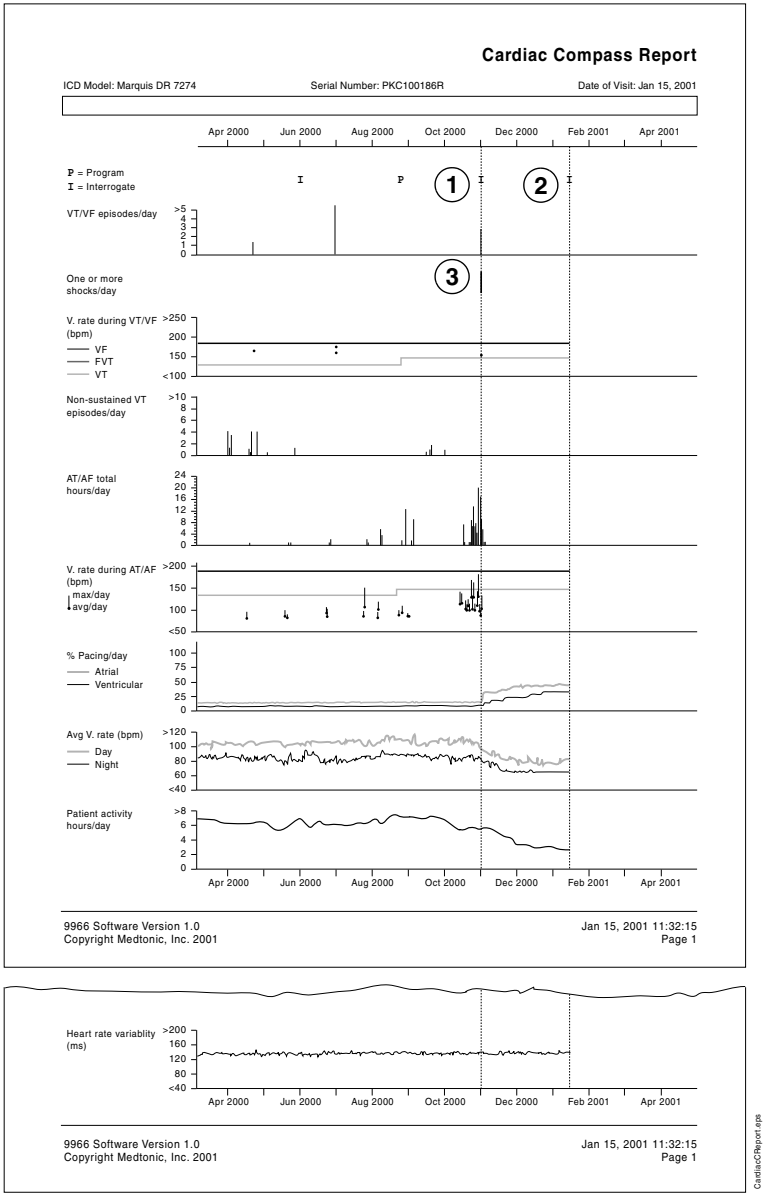
Data storage for the Cardiac Compass report is automatic. No setup is required. The device begins storing data when VF Detection is programmed On at implant. Each day thereafter, the device stores a set of Cardiac Compass data. Storage continues until the 14-month storage capacity is filled. At that point, the oldest stored data is overwritten with new data.

The times displayed on the report are based on the device clock.

You can print the report from either a full size printer connected to the programmer or from the programmer strip chart recorder.

- A report printed from the strip chart includes all 11 trends on several printer pages.
- A report printed on a full size printer includes only 10 trends on one page. When printing to a full size printer, you can select to include either the Heart Rate Variability trend or the NST trend in the report.

Figure 12-10. Cardiac Compass Report example

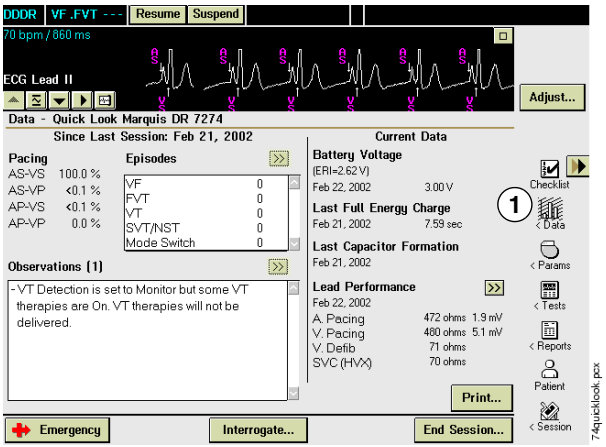


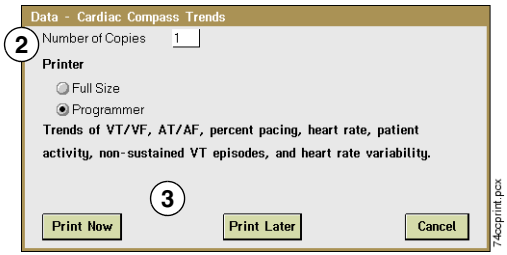
1 Last session indicator

2 Current session indicator

3 High voltage therapy indicator

How to print a Cardiac Compass report





Interrogate the device if you have not already done so.

1. Select Data icon > Cardiac Compass Trends ... .
2. Select print options for
   - number of copies
   - printer type
3. Select [Print Now] or [Print Later] to print the Cardiac Compass report.

Details on Cardiac Compass trend data

Programming and interrogation annotations

The programming and interrogation annotations provide all of the following indications:

- when the patient has been seen
- when device parameters have been changed
- possible cause and effect correlations between device parameter changes and other clinical trends

The report records an “I” value for a day on which the device is interrogated and a “P” value for a day on which any programmable parameter is changed (except for temporary changes such as changes to test parameters). If both “I” and “P” values are recorded for a day, only the “P” is displayed on the report.

VT/VF episodes per day

The VT/VF episodes per day trend provides a history of ventricular tachyarrhythmias and may be helpful in revealing correlations between clusters of episodes and other clinical trends. Each day, the device records the total number of spontaneous VT and VF episodes. The episode counts are provided in histogram format on the report.

One or more shocks per day

The device records a high voltage therapy indicator for any day on which it delivers an automatic defibrillation or cardioversion therapy. The Cardiac Compass report displays a “I” annotation for the day on which a defibrillation or cardioversion therapy was delivered.

Ventricular rate during VT, FVT, and VF

The Cardiac Compass report displays a graph of the daily median ventricular rate for spontaneous VF, FVT, and VT episodes which may have occurred. This may provide an indication of the effects of anti-arrhythmic drugs on VF, FVT, and VT rates and a better understanding of the safety margins for detection.

Every day, the device stores each unique ventricular median interval occurring on that day. The stored median interval values are converted to ventricular rate and displayed on the report as points on the graph. The report also plots the programmed VF, FVT, and VT interval values for each day.

Non-sustained VT episodes per day

The non-sustained VT episodes trend may help correlate patient symptoms (such as palpitations) to NST episodes and may indicate a need for further investigation of the status of the patient. Each day, the device records the total number of spontaneous NST episodes. The episode counts are provided in histogram format on the report. Episodes during which detection is withheld due to SVT Criteria are not counted as NSTs.

AT/AF total hours per day

The AT/AF total hours per day trend may help to assess the need for anti-arrhythmic drugs to reduce AF/AT episode occurrences or for anti-coagulant drugs to reduce the risk of stroke.

The device records a daily total for the time the patient spent in AT or AF. It defines AT or AF episodes using the same detection criteria as the Mode Switch feature. The time (in hours) is provided in histogram format on the report. This trend may be reported in minutes (1-60) per day depending on the episode frequency.

Ventricular rate during AT/AF

The ventricular rate during AT/AF trend can be used to do one of the following:

- correlate patient symptoms to rapid ventricular responses to AT/AF
- assess VT/VF detection safety margins and modify programming to avoid treating AT/AF as VT/VF
- prescribe or titrate anti-arrhythmic and rate control drugs
- assess the efficacy of an AV node ablation procedure

The device records average and maximum ventricular rates during episodes of AT and AF each day. The values are plotted on the Cardiac Compass report along with the average ventricular rates.

Percent pacing per day

The percent pacing per day graph provides a view of pacing over time that can help identify pacing changes and trends. It displays the percentage of events occurring during each day that were atrial paces and ventricular paces. These percentages are calculated from the stored daily totals of the AS-VS, AS-VP, AP-VS, and AP-VP counters.

Patient activity

The patient activity trend can be used in these ways:

- as an early indicator of symptoms due to progressive diseases like heart failure, which cause fatigue and a consequent reduction in patient activity
- as an objective measurement of patient response to changes in therapy
- to study outcomes in ICD patients (along with measures like quality of life)
- to monitor a patient's exercise regimen

The device uses activity count data derived from the rate response accelerometer signal to determine patient activity. It stores activity values daily, and for each seven days of stored data, it calculates a seven-day average, which is plotted for the Cardiac Compass report.

Day and night heart rates

The day and night heart rates trend may be clinically useful by

- showing gradual increases in heart rate, which indicate decompensation, a symptom of heart failure
- providing objective data to correlate with patient symptoms
- indicating autonomic dysfunction or heart failure
- providing information regarding diurnal variations
- showing the patient's true heart rate, independent of effects like "white coat syndrome"

For this trend, the device defines "day" as the 12-hour period between 8:00 AM and 8:00 PM and "night" as the 4-hour period between midnight and 4:00 AM (as indicated by the device clock).

The device calculates the daytime and night-time averages of interval length from the stored data and converts these values to rates for graphing. The values exclude any ventricular intervals that

- occur during a manual temporary operation
- are identified by the device as VF, FVT, or VT events
- occur during a detected episode (between detection and episode termination)
- occur during a Mode Switch or AF/AT episode

Heart rate variability

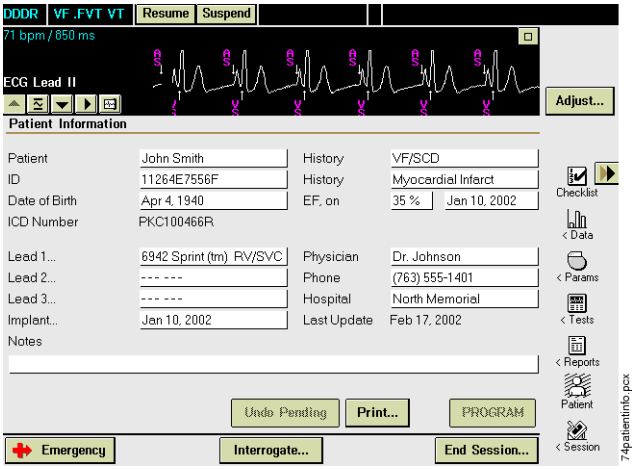
The device measures the median atrial interval value every five minutes and calculates a variability value each day. The variability value (in milliseconds) is plotted on the Cardiac Compass report.

Viewing and entering patient information

Patient information is typically entered at the time of initial implant, and it can be revised at any time. This information is stored in the device and can be accessed by the programmer. Patient information includes

- patient name, ID number, date of birth, medical history, and physician and hospital name
- ICD and lead system identification and implant information
- implant testing data

Figure 12-11. Patient Information screen



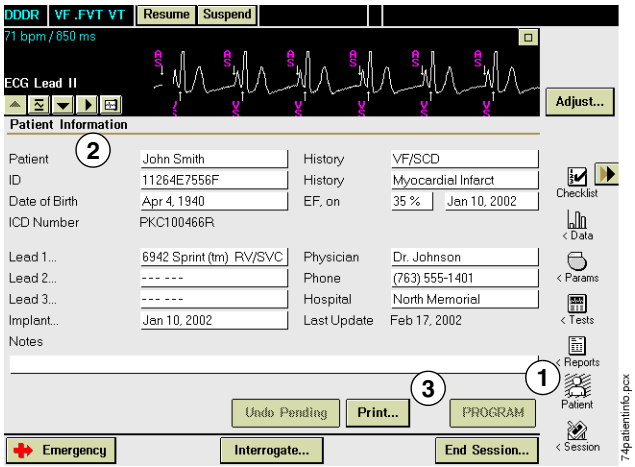
Note: The Patient Information screen should not be used in the place of the patient's medical chart (see the legal notice on page xvi).

Table 12-3. Description of Patient Information parameters

Information field	Description and required action
Patient	Enter the patient name (up to 30 characters).
ID	Enter the patient ID (up to 15 characters).
Date of Birth	Select patient's date of birth.
ICD Number (Not selectable)	Displays serial number for implanted device after interrogation.
Lead 1 . . . Lead 2 . . . Lead 3 . . .	Enter detailed information for leads 1, 2, and 3: Model; Position: pick from list of positions, or enter position; Serial Number; Manufacturer; and Implant date.
Implant	Enter measured values from implant. Using the displayed submenu, enter new information including lead data from the Analyzer.
Notes	Enter notes about patient or other information.
History (2 fields)	Select medical history from list box. If necessary, you can indicate that more information is located in the Notes field.
EF, on	Select the ejection fraction from a table of values. Then enter the date in the following field.
Physician	Select or add the name of the physician. You can also enter the physician's phone number at the same time.
Phone	Enter the phone number of the physician.
Hospital	Select or add the hospital information.
Last Update (Not selectable)	Displays the date of the last Patient Information update.

Note: The ICD serial number and patient name and ID number are printed on each page of all full-size and strip chart reports.

How to view and enter new patient information



1. Select the Patient icon. The Patient Information screen is displayed.
2. Select the data field you want to change, and enter the text for the field, or if a display list appears, do one of the following:
   a. Select an option from the display list, or
   b. Select [Modify List] and [Add]. Then type in your addition and select [OK].
3. When all the information has been entered, select [PROGRAM].

Displaying and printing patient information

If you make an entry that does not fit in the parameter display area, the entry is truncated on the display, but the entry is visible if printed from the Patient Information screen.

When displayed or printed from the Changed Parameters screen, information may be truncated, which is indicated by an ellipsis (...) following the last character.

Interlock markers are displayed if patient information has not been entered. However, programming patient information is not required.

You can print current patient information from the Patient Information screen or the Reports icon:

- From the Patient Information screen, select [Print...]. Choose the number of copies and printer (Full Size or Programmer), and then select [Print Now] or [Print Later].
- Select the Reports icon and select [Custom...]. Select [All Settings] under the Parameters heading. Select [Print Options] to choose the number of copies and the printer (Full Size or Programmer), then select [Print Now] or [Print Later].

Note: The ICD serial number, patient, and ID number fields are printed on all full-size and strip chart reports.

Automatic device status monitoring

During each interrogation, the device is monitored for adequate charge time performance and possible electrical reset conditions. If a condition is detected that requires attention, the programmer displays a Device Status Indicator warning in a pop-up window and on the Quick Look screen.

Device status indicator warnings

⚠ **Warning:** The Device Status Indicators are important. Please inform your Medtronic representative if any of the indicators are displayed after interrogating a device.

The Device Status Indicators are defined below:

Warning - Charge Circuit Timeout – Indicates that the charging period has exceeded 30 seconds. The charge circuit is still active. Please inform your Medtronic representative if this Device Status Indicator occurs. **Immediate replacement is recommended.**

Warning - Charge Circuit Inactive – Indicates that three consecutive charging periods have each exceeded 30 seconds. The charge circuit is inactive, and all automatic therapy functions and manual operations are disabled except for Emergency VVI pacing. Please inform your Medtronic representative if this Device Status Indicator occurs. **Immediate replacement is recommended.**

Warning - ICD Electrical Reset – Indicates that an electrical reset has occurred. Programmed parameters may have been set to electrical reset values.[1] Read the message accompanying the indicator, and follow the screen instructions carefully. If the error message does not indicate that parameters have been reprogrammed, then the reset did not affect any programmed parameters.

In some cases, an electrical reset may disable tachyarrhythmia detection and therapy. If this occurs, the electrical reset patient alert sounds every 9 hours, and the device operates as a simple bradycardia pacing device (in VVI mode, 65 ppm).

[1] See Appendix B, "Device Parameters" on page 367 for reset settings.

Warning - SERIOUS ICD ERROR – Indicates an error has occurred from which the device cannot recover. If this message is displayed, **immediate replacement is recommended.**

Clearing displayed status indicators

To clear the displayed status indicator, select [Clear] from the pop-up window displaying the Device Status Indicator message.

How to respond to an electrical reset

If the programmer reports that an electrical reset occurred, follow these steps:

1. Notify your Medtronic representative.
2. Remove any sources of electromagnetic interference (EMI).
3. Select [Clear] in the pop-up window to clear the reset indicator and the Patient Alert alarm.

   A confirmation window appears indicating that all previously interrogated data in the programmer will be cleared.
4. Select Continue.
5. Interrogate the device.
   a. Note the time and date when counter data was last cleared, because this indicates when the electrical reset occurred.
   b. Determine, if possible, what the patient was doing at that time and date.
   c. Save your session data to disk. You should give this saved data file to your Medtronic representative; it will be helpful in determining the events leading up to the reset.
6. Verify the programmed device parameters. Depending on the type of reset that occurred, you may need to reprogram the device parameters.

   If the electrical reset did reprogram certain parameters, the reprogrammed values are displayed in the error message. After this type of reset, the device operates as a simple defibrillator (in VOE-VVI mode), until reprogrammed. For a list of electrical reset parameter settings, see Appendix B, "Device Parameters" on page 367.
7. Verify the correct Device Date/Time. If necessary, reprogram the date and time.
8. Perform a manual capacitor formation to reset the capacitor formation timer and ensure that the capacitor formation schedule is not compromised.
9. Interrogate the device again. Check the Battery and Lead Measurements screen to verify that the battery voltage and charge time are acceptable.
10. Conduct Lead Impedance and Pacing Threshold tests as desired.

Key terms

Cardiac Compass report – printed plot of up to 14 months of daily measurements, used to identify and document long-term clinical trends.

Charge Circuit Timeout – indicates that the charging period has exceeded 30 seconds. The charge circuit is still active. Please inform your Medtronic representative if this Device Status Indicator occurs. **Immediate replacement is recommended.**

Charge Circuit Inactive – indicates that three consecutive charging periods have each exceeded 30 seconds. The charge circuit is inactive, and all automatic therapy functions and manual operations are disabled except for Emergency VVI pacing. Please inform your Medtronic representative if this Device Status Indicator occurs. **Immediate replacement is recommended.**

charging period – time required for the device to store the programmed energy (charge) in its capacitors so that it can rapidly deliver a cardioversion or defibrillation therapy.

counter data – stored data including numbers of episodes, delivered therapies, and therapy outcomes. This data is displayed via the Data icon.

Decision Channel annotations – annotations to stored and telemetered EGMs, documenting some details of dual chamber tachyarrhythmia detection.

device status indicators – programmer messages describing the device memory, capacitor, and electrical reset status.

EGM range – maximum magnitude of EGM amplifier signal, in millivolts. Smaller settings result in a higher resolution for displayed and recorded EGM waveforms.

EGM source – the pair of implanted electrodes selected as the sensing pathway for stored and telemetered EGM signals.

EGM strip – stored recording of the intracardiac waveforms from a detected arrhythmia episode.

Elective Replacement Indicator – see “ERI.”

electrical reset – automatic device operation to recover from a disruption in device memory and control circuitry. Programmed parameters may be set to electrical reset values.[1] This operation triggers a device status indicator and an automatic Patient Alert tone.

EOL (End of Life) – battery status indicator for when immediate replacement of the device is recommended. The programmer displays the EOL symbol to indicate that the device is at End of Life and may not operate per specifications.

episode record – stored information about the cardiac rhythm and device behavior during a detected tachyarrhythmia episode.

ERI (Elective Replacement Indicator) – battery voltage or charge time at which replacement of the device is recommended; ERI does not alter the device operation in any way.

far-field EGM – the EGM signal sensed between distant electrodes, for example, the EGM sensed between the device can and the ventricular lead ring. This term can also refer to the far-field sensing of R-waves by an atrial lead or sensing of P-waves by a ventricular lead.

Flashback memory – programmer display of the A-A and V-V intervals that preceded recent episodes or that preceded the last interrogation of the device.

Holter Telemetry – telemetry feature that transmits EGM and Marker Channel data continuously for a programmable number of hours, regardless of whether the programming head is positioned over the device.

impedance – total opposition that a circuit presents to electrical current flow. The impedance on the leads connected to the device can be measured to assess the lead system’s integrity.

[1] See Appendix B, "Device Parameters" on page 367 for reset settings.

interlock – safety restriction in the programmer software that aids in the choice of proper parameter values, usually by displaying a screen message.

Last Session – the most recent time the device was successfully interrogated.

Lead Performance Trends – displays lead impedance and EGM amplitude graphs for up to 80 weeks (accessed via Quick Look, Battery and Lead Measurements, and Lead Impedance Test screens).

Marker Channel telemetry – telemetered symbols that annotate the device sensing, pacing, detection, and therapy operations.

near-field EGM – the EGM signal sensed across two closely spaced electrodes, for example, the EGM sensed between the tip and ring of an atrial or ventricular lead. Sometimes referred to as a bipolar EGM.

Non-Sustained Tachycardia (NST) – ventricular rhythm that is fast enough to fall within the programmed VT and VF zones for at least five beats, but does not meet any episode detection criteria.

PR Logic criteria – (A.Fib/A.Flutter, Sinus Tach, and Other 1:1 SVTs) optional detection criteria that analyze both atrial and ventricular rhythms to discriminate between ventricular and supraventricular arrhythmias.

Pre-Onset EGM Storage – (also called EGM pre-storage) programmable option to record EGM continuously. If a tachyarrhythmia episode occurs, the pre-onset EGM is added to the episode record to document the rhythm at onset.

QuickLink software design – navigation feature that provides easy, direct access between related programmer screens.

Quick Look software display – programmer screen that provides a summary of device status, notable events since the last interrogation, counters, and programming observations.

Sensing integrity counter – records the number of short ventricular intervals that occur between patient sessions[1]. The sensing integrity counter records any sensed ventricular event with a V-V interval shorter than 140 ms (unless the previous ventricular event was paced) since the last session.

successful – therapy counter that indicates how many times the therapy's outcome was episode termination.

telemetry – communication between the device and the programming head by radio waves. Programming commands, status messages, and stored episode records are all transmitted by telemetry.

unsuccessful – therapy counter that records how many times this therapy resulted in redetection, rather than episode termination.

[1] Defined as intervals since stored data was cleared or the last session ended.

Testing the system

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Testing overview

You can use the manual tests provided by the device to evaluate system performance and integrity. The device offers five options for testing the system, which are available from the Tests icon:

- Underlying Rhythm test
- Pacing Threshold test
- Lead Impedance test
- EGM Amplitude test
- Charge/Dump test

For more information about EP Study operations, which are also available via the Tests icon, see Chapter 14, "Conducting Electrophysiologic Studies" on page 323.

△ **Caution:** During system tests, tachyarrhythmia detection and therapies are suspended.

Evaluating the underlying rhythm

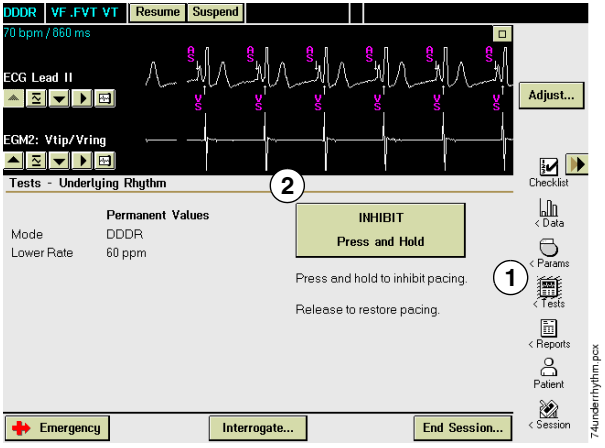
Using the Underlying Rhythm Test, you can inhibit the pacing output of the device to evaluate the patient's natural heart rhythm.

Considerations

Review the following information before performing the Underlying Rhythm test.

△ **Caution:** Use caution when performing the Underlying Rhythm test on patients who depend on pacing for adequate cardiac output. The device delivers no pacing as long as you press and hold the [INHIBIT Press and Hold] button.

How to Perform an Underlying Rhythm test



1. Select Tests > Underlying Rhythm.
2. Select [INHIBIT Press and Hold]. A message indicates that the test is inhibiting pacing.
3. To obtain a recording of the patient's natural rhythm, press the desired paper speed key on the printer/recorder. The ECG trace should not show any pacing stimuli.

Measuring pacing thresholds

You can determine the patient's atrial and ventricular pacing stimulation thresholds using the Pacing Threshold test. The test consists of three parts:

- selecting temporary pacing parameters for the test
- delivering pacing pulses that capture the heart
- gradually decreasing the pulse width, automatically or manually, until pacing capture is lost

After performing a Pacing Threshold test, make sure that the permanently programmed pulse width and amplitude parameters provide an adequate safety margin above the measured pacing threshold value.

You can choose to decrease the pacing pulse width manually (Manual) or have the device decrease the pacing pulse width automatically (Pulse Width - Auto Decrement).

Note: Interrogate the device before performing a Pacing Threshold Test to ensure that the temporary pacing parameters it applies correspond to those programmed for the patient.

Parameters

* Medtronic nominal setting

Test Type – Method to use for modifying the pacing outputs (manual or automatic).	Manual, Pulse Width - Auto Decrement*
Chamber – The chamber of the heart where the pacing threshold is tested.	Ventricle*, Atrium
Mode[a] **–** Pacing mode used during the test.	Atrial test: AAI, DDI, DDD* Vent. test: VVI*, DDI, DDD
Lower Rate[a] **– (**ppm, min^{-1}) Minimum pacing rate used during the test.	30, 35, . . . 60, 70, 75, . . ., 90*, . . ., 150[b]
AV Delay[a] (ms) **–** Interval between an atrial event and a following ventricular pace.	30, 40, . . ., 150*, . . ., 350
V. Amplitude[a] (V) **–** Voltage setting for ventricular pacing pulses delivered during the test.	0.5, 1, . . ., 3*, 3.5, 4, 5, 6
V. Pulse Width[a] (ms) **–** Duration of the ventricular pacing pulses delivered during the test.	0.03, 0.06, 0.1, 0.2, 0.3, 0.4*, . . ., 1.6
A. Amplitude[a] (V) **–** Voltage setting for atrial pacing pulses delivered during the test.	0.5, 1, . . ., 3*, 3.5, 4, 5, 6
A. Pulse Width[a] (ms) **–** Duration of the atrial pacing pulses delivered during the test.	0.03, 0.06, 0.1, 0.2, 0.3, 0.4*, . . ., 1.6
V. Pace Blanking[a] (ms) **–** Time interval during which sensing is disabled after a ventricular pacing pulse.	150, 160, . . ., 200*, . . ., 440
A. Pace Blanking[a] (ms) **–** Time interval during which sensing is disabled after an atrial pulse.	150, 160, . . ., 200*, . . ., 250
PVARP[a] (ms) **–** Atrial refractory period following ventricular events which prevents atrial oversensing.	150, 160, . . ., 310*, . . ., 500

[a] The default value for this parameter is set according to the permanently programmed settings for bradycardia pacing if the device has been interrogated. Otherwise it defaults to the indicated nominal value.

[b] The maximum range value is dependant on the programmed pacing mode.

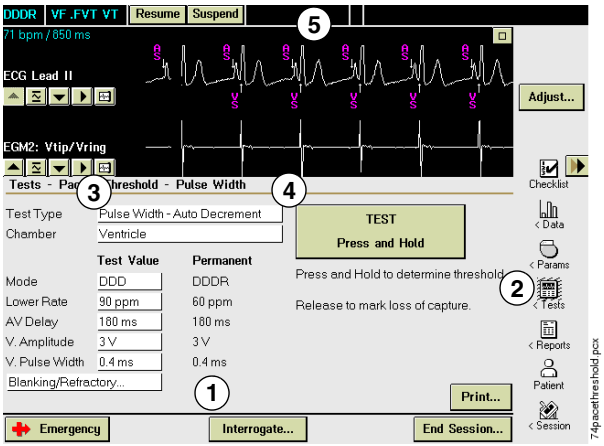
Note: The selectable and default values provided by the Pacing Threshold test depend on the programmed values for bradycardia pacing therapy.

Considerations

Review the following information before performing the Pacing Threshold test.

Decreasing the pulse width – You can choose to decrease the pacing pulse width manually or have the device decrease the pacing pulse width automatically.

How to perform a Pacing Threshold Test



1. Interrogate the device by selecting the [Interrogate] button.
2. Select Tests > Pacing Threshold.
3. Select Test Type, Chamber, and starting test values, or accept the values displayed.
4. Press and hold [TEST Press and Hold].
5. Observe the ECG for loss of capture. If consistent capture is verified
   - In a Manual test: adjust the Pulse Width setting and repeat the test.
   - In an Auto Decrement test: verify the test has decreased the pulse width.
6. When capture is lost, immediately release [TEST Press and Hold]. The device resumes its pre-test pacing values and the final test values remain displayed.

Measuring lead impedance

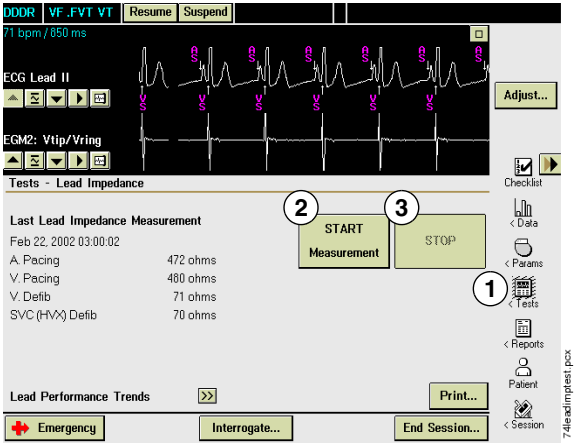
You can test the integrity of the implanted lead system by measuring the impedance across the ventricular pacing, atrial pacing, and high voltage electrodes with the Lead Impedance test. These measurements are made without delivering a high voltage shock or pacing pulses that capture the heart. Instead, the device uses low voltage, sub-threshold pulses, resulting in painless testing for the patient.

Considerations

Review the following information before performing the Lead Impedance test.

Sensing measurement pulses – When the device performs a lead impedance measurement, it may sense the sub-threshold test pulses as atrial refractory events (or atrial sensed events in VVI mode). These pulses may also cause very small variations on one or more of the EGM channels. However, pulses delivered by a Lead Impedance test do not capture the heart or affect tachyarrhythmia detection.

How to perform a Lead Impedance test



1. Select Tests > Lead Impedance.
2. Select [START Measurement]. Wait for programming confirmation and an in-progress message and graphic display.
3. If necessary, you can abort the test by selecting [STOP]. Lead impedance measurements are not updated from an aborted test.

Details about the Lead Impedance test

The Lead Impedance test delivers small sub-threshold pulses between several electrode combinations and then measures any changes in voltage. The electrical current is measured across the electrodes and converted to an impedance value.

Impedance measurement synchronization

When performing a Lead Impedance test, measurements across the ventricular pacing lead and the high voltage electrodes are synchronized to ventricular paced or sensed events, and measurements across the atrial pacing lead are synchronized to atrial paced or sensed events.

The device cannot synchronize lead impedance measurements to the following events:

- atrial sensed events that occur during the PVAB
- ventricular sensed events that occur during a VSP interval

For each measurement, the Lead Impedance test waits up to three seconds for an event that qualifies for synchronization. If no qualifying event occurs, the measurement is delivered asynchronously.

Automatic lead impedance testing

In addition to manually-initiated impedance measurements, the device performs daily automatic lead impedance measurements.

High voltage therapy impedance

When a high voltage therapy is delivered, the high voltage lead impedance is measured based on the energy of the shock rather than sub-threshold pulses. This measurement is displayed under the Last High Voltage Therapy category on the Battery and Lead Measurements screen.

Measuring EGM Amplitude

You can assess lead integrity and sensing performance using the EGM Amplitude test. During this test, the device measures the base-to-peak voltage of sensed atrial and ventricular events. To increase the likelihood that sensed events will occur, you can select temporary pacing settings that evoke the patient's intrinsic rhythm.

△ **Caution:** Use caution when selecting temporary pacing settings for pacemaker dependant patients.

You can determine if the sensing performance of the device has changed by comparing the measured values to those reported on the Lead Performance Trends screen and those measured at previous follow-ups.

Parameters

* Medtronic nominal setting

Mode – Pacing mode used during the test.	AAI, DDD, DDI, VVI, ODO
AV Delay (ms) **–** Interval between an atrial event and a following ventricular pace.	30, 40, . . . , 350
Lower Rate (ppm, min^{-1}) **–** Minimum pacing rate used during the test.	30, 35, . . ., 60, 70, 75, . . ., 120[a]

[a] The maximum range value is dependant on the programmed pacing mode.

Considerations

Review the following information before performing the EGM Amplitude test.

Selecting sensitivity values – Do not adjust the values for A. Sensitivity and V. Sensitivity based on the results of this test. See "How to program sensitivity" on page 63.

Patient comfort – Reducing the pacing rate gradually may help minimize symptoms associated with abrupt changes in heart rate.

Pacing modes – Available modes depend on the permanently programmed pacing mode, including DDD, DDI, VVI, and AAI.

Automatic time-out – The test ends automatically after a few seconds and restores the programmed settings if no intrinsic events occur and you make no changes to the pacing rate.

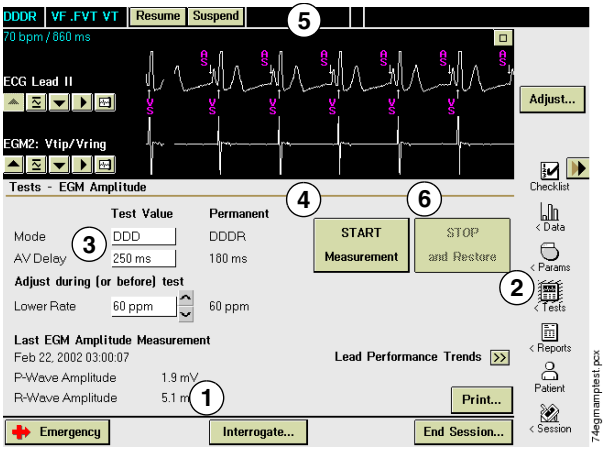
Maximum measured values – When the sensitivity is set to between 0.3 mV and 2.1 mV, the maximum amplitude values that the EGM Amplitude test can measure are 10.7 mV for atrial (P-wave) and 18.8 mV for ventricular (R-wave) measurements. However, if the sensitivity setting is set to 0.15 mV, the maximum amplitude values that the EGM Amplitude test can measure are 5.35 mV for atrial (P-wave) and 9.4 mV ventricular (R-wave) measurements.

Restrictions

Review the following information before performing the EGM Amplitude test.

DOO and VOO pacing modes – The EGM Amplitude test cannot be performed if the programmed pacing mode is DOO or VOO.

How to perform an EGM Amplitude test



1. Interrogate the device by selecting the [Interrogate] button.
2. Select Tests > EGM Amplitude.
3. Set the pacing Mode and AV Delay (when available) for the test, or accept the values displayed.
4. Select [START Measurement]. The parameter values that you selected are enabled.
5. Observe the Live Rhythm Monitor for intrinsic rhythm. If consistent pacing is still occurring, decrease the Lower Rate.
6. If necessary, you can abort the test by selecting [STOP and Restore]. Pacing settings will return to the programmed values.

Testing the device capacitors

The Charge/Dump test allows you to test charge time, manually form the device capacitors, and dump any charge remaining on the capacitors.

After a test charge, the charge remains on the capacitors until it is dumped, delivered by a cardioversion or defibrillation therapy, or dissipates (after about 10 minutes).

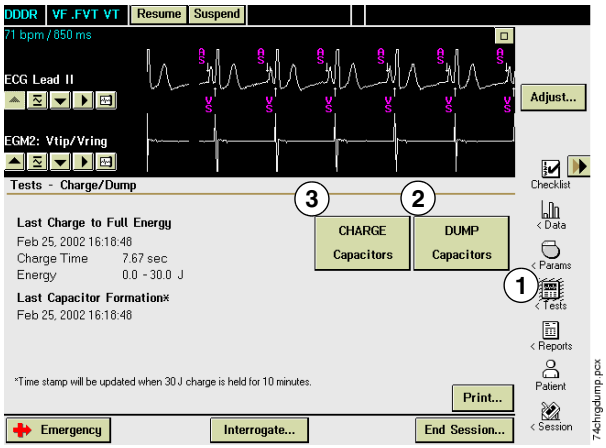
For more information about using the Charge/Dump test to manually form the capacitors, see “Details about managing charge time” on page 205.

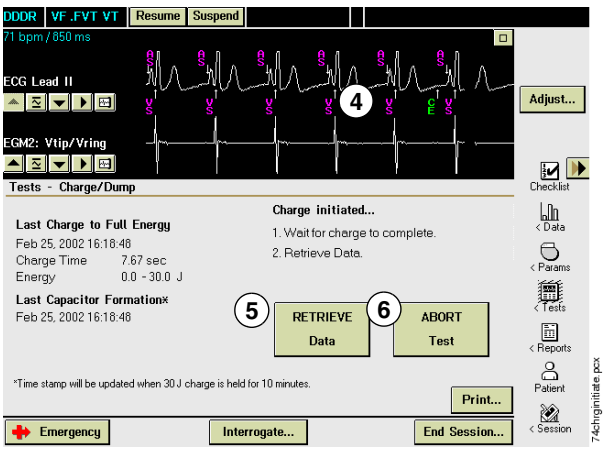
Considerations

Review the following information before performing the Charge/Dump test.

Manual capacitor formation – If you allow a test charge to dissipate for 10 minutes, the device records it as a capacitor formation and resets the automatic capacitor formation interval.

How to perform a Charge/Dump test





1. Select Tests > Charge/Dump.
2. Select [DUMP Capacitors] to remove any charge from the capacitors.
3. Select [CHARGE Capacitors]. The message “Manual operation charging” appears on the Device Status Line.
4. When charging has completed, the Charge End symbol (CE) appears on the Marker Channel display and the Manual Operation Charging message disappears from the screen heading.
5. Select [RETRIEVE Data] to collect the charge time data from the device.
6. If necessary, you can abort the test charge by selecting [ABORT Test].

Key terms

capacitor – electrical component in the device that stores electrical energy so that a high voltage can be delivered from a relatively small battery.

capacitor formation – any charge to maximum programmed energy that dissipates off the capacitors (is not dumped or delivered) for at least ten minutes.

charging period – time required for the device to store the programmed energy (charge) in its capacitors so that it can rapidly deliver a cardioversion or defibrillation therapy.

impedance – total opposition that a circuit presents to electrical current flow; the device lead impedances can be measured to assess the lead system's integrity.

Inhibit – temporary function that prevents pacing output pulses.

pacing threshold – minimum programmable pacing output that consistently captures the heart.

Quick Look software display – programmer screen that provides a summary of device status, notable events since the last interrogation, counters, and programming observations.

sensitivity – degree to which the device sensing circuitry is responsive to intracardiac voltages.

test values – temporary parameters used during system test and EP study operations. Permanent settings are restored automatically once the operation has ended, the programming head is removed, or the telemetry link is broken.

undersensing – failure to sense the P-wave or R-wave; can cause failure to detect a tachyarrhythmia or inappropriate bradycardia pacing.

Conducting Electrophysiologic Studies

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EP Study overview

⚠ **Warning:** Perform EP Study functions only under careful patient monitoring and control. Keep an external defibrillator immediately available and on standby during EP Study operations. An induced ventricular tachycardia may degenerate to ventricular fibrillation.

The device provides electrophysiologic study (EP Study) functions via the **Tests** icon. EP Study functions include cardiac stimulation protocols that induce VF, VT, and AT/AF:

- T-Shock VF induction
- 50 Hz Burst pacing
- atrial and ventricular Manual Burst pacing
- atrial and ventricular Programmed Electrical Stimulation (PES)

EP Study also provides each of the tachyarrhythmia therapies, executed manually via a telemetry command from the programmer:

- Defibrillation
- Cardioversion
- Burst pacing
- Ramp pacing
- Ramp+ pacing

Each manual therapy performs in the same way as the automatic therapy with additional temporary settings for timing and output.

Detection suspended during manual therapy – Delivering a manual therapy suspends tachyarrhythmia detection. To resume detection, press the on-screen [Resume] button, or remove the programming head from the implanted device.

Auto resume after induction – All of the EP Study inductions provide the option to automatically resume detection after the induction is delivered. Select the [Resume at BURST] or [Resume at DELIVER] checkbox to enable auto resume.

Temporary parameter values – EP Study operations use test values that do not change the programmed parameters of the device. Test values are not in effect until you begin the induction or therapy. After the induction or therapy, the device reverts to its programmed parameter values for bradycardia pacing and tachyarrhythmia therapy.

Pacing operations – The following bradycardia operations are suspended during an EP Study operation: Non-Competitive Atrial Pacing, PMT Intervention, Hysteresis, Sensor-Varied PVARP, Rate Adaptive AV, Rate Response calculations, Ventricular Rate Stabilization, and Mode Switch.

Programmed parameters check – Before displaying the EP Study screen, the system checks to verify that the device is programmed to detect and treat an induced arrhythmia. If the detection or therapy features are not programmed appropriately, a warning message appears on screen.

Programming head buttons – The Program and Interrogate buttons on the programming head are disabled during EP Study inductions. Use the appropriate on-screen delivery button to perform an induction.

Inducing VF with T-Shock

The T-Shock induction is designed to induce VF by delivering a shock simultaneously with a T-wave, the vulnerable period of the cardiac cycle. You can use T-Shock inductions to test the effectiveness of the programmed detection and therapy parameters, for example, during defibrillation threshold (DFT) testing.

To simplify DFT testing, the following tasks can all be performed using the T-Shock screen:

- monitor the time between inductions
- reprogram sensing and VF therapy settings
- adjust the induction settings
- retrieve episode records after therapy

See details about T-Shock induction on page 328.

Parameters

* Medtronic nominal setting

#S1 – Number of pulses in the VOO pacing sequence.	2, 3, . . ., 8*
S1S1 (ms) **–** Pacing interval of the VOO pacing sequence.	300, 310, . . ., 400*, . . ., 2000
Delay (ms) **–** Maximum interval between the final VOO pulse and the T-Shock.[a]	50, 60, . . ., 310*, . . ., 600
Energy (J) **–** Energy delivered by the T-Shock induction.	0.4, 0.6*, . . ., 1.8, 2, 3, . . ., 16, 18, 20, . . ., 30
Waveform – Voltage pattern of the delivered shock.	Monophasic*, Biphasic
Pathway – Direction that current travels through the heart.	AX>B*, B>AX
Amplitude (V) **–** Voltage of each pulse in the pacing sequence.	8 V (fixed)
Pulse Width (ms) **–** Duration of each pulse in the pacing sequence.	1.6 ms (fixed)

(continued)	* Medtronic nominal setting
Enable – (checkbox) Safety lock that enables T-Shock induction.	Enabled, Disabled*
Resume at DELIVER – (checkbox) Option to resume detection automatically when the induction is delivered.	Enabled*, Disabled

[a] The T-Shock is delivered on a ventricular sensed event or at the end of the selected Delay interval, whichever comes first.

Considerations

Review the following information before performing the T-Shock induction.

⚠ **Warning:** Keep an external defibrillator immediately available and on standby.

Detection and auto resume option – If the [Resume at DELIVER] option is selected, the device automatically resumes tachyarrhythmia detection after the induction. To deliver an induction with automatic detection suspended, select the on-screen [Suspend] button and de-select the [Resume at DELIVER] checkbox.

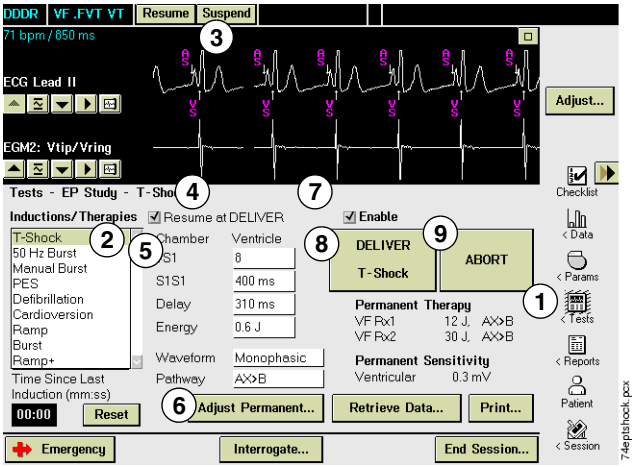
Aborting an induction or therapy – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

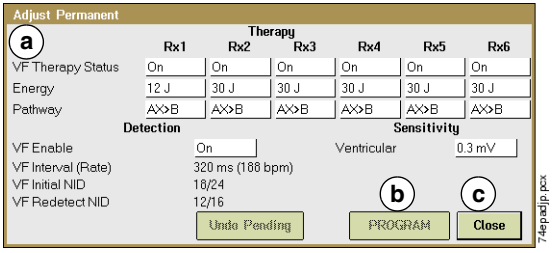
Restrictions

Review the following information before performing the T-Shock induction.

[Enable] checkbox – As a safety measure, you cannot select the [DELIVER T-Shock] button until you have selected the T-Shock [Enable] checkbox. After you deliver a shock or exit the T-Shock screen, you must re-select the [Enable] checkbox before delivering another T-Shock induction.

How to deliver a T-Shock induction





1. Select Tests > EP Study.
2. Select T-shock from the Inductions/Therapies box.
3. If you wish to treat the induced episode with a manual therapy, select [Suspend] to prevent automatic detection.
4. Confirm that the [Resume at DELIVER] checkbox is selected (for automatic detection and therapy) or is deselected (for manual therapy).
5. Accept the test values displayed on the screen, or choose new test values.
6. Accept the sensing and VF therapy values displayed on the screen, or select [Adjust Permanent...]
   a. Select new sensing and VF therapy values if desired.
   b. Select [PROGRAM].
   c. Select [Close].
7. Select the [Enable] checkbox.
8. Select [DELIVER T-Shock].
9. If necessary, you can use the [ABORT] button to terminate the induction or any therapy in progress.

Details about T-Shock induction

A T-Shock VF induction delivers two to eight VOO pacing stimuli, then delivers a shock. The shock is delivered on a ventricular sensed event or at the end of the selected Delay interval, whichever comes first. The intent of this protocol is to force the ventricular cycle into a predictable rhythm and then deliver the shock simultaneously with a T-wave, the vulnerable period of the cardiac cycle, in order to induce VF.

If the stored energy on the capacitors is higher than the energy level you selected, the programmer displays a warning when you select the [DELIVER T-Shock] button. To clear this warning from the screen, select either [DUMP] or [CANCEL].

Inducing VF with 50 Hz Burst

The 50 Hz Burst induction is designed to induce VF by delivering a rapid burst of pacing pulses. The amplitude and pulse width of these pulses are selectable, but the pacing interval is fixed at 20 ms. You can use 50 Hz Burst inductions to test the effectiveness of the programmed detection and therapy parameters, for example, during defibrillation threshold (DFT) testing (see page 42). To simplify DFT testing, the following tasks can all be performed using the 50 Hz Burst screen:

- monitor the time between inductions
- reprogram sensing and VF therapy settings
- adjust the induction settings
- retrieve episode records after therapy

See details about 50 Hz Burst induction on page 332.

Parameters

* Medtronic nominal setting

Interval (ms) – Pacing interval of the 50 Hz Burst induction.	20 ms (fixed)
Amplitude (V) – Voltage of each pulse in the pacing sequence.	0.5, 1, . . ., 4, 5, 6, 8*
Pulse Width (ms) – Duration of each pulse in the pacing sequence.	0.03, 0.06, 0.1, 0.2, . . ., 1.6*
Resume at BURST (checkbox) – Option to resume detection automatically when the induction is delivered.	Enabled*, Disabled

Considerations

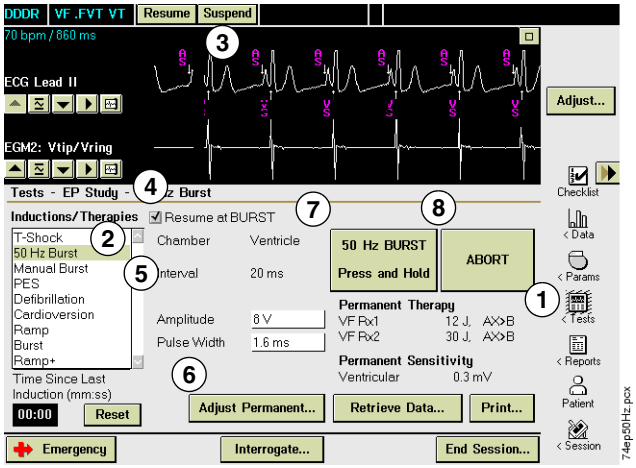
Review the following information before performing the 50 Hz Burst induction.

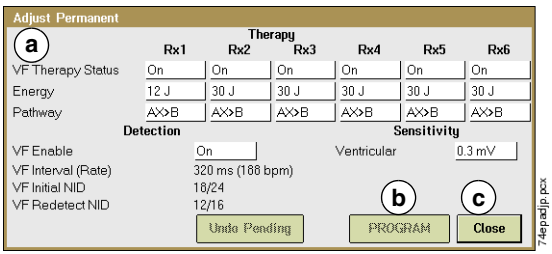
⚠ **Warning:** Keep an external defibrillator immediately available and on standby.

Detection and auto resume option – If the [Resume at BURST] option is selected, the device automatically resumes tachyarrhythmia detection after the induction. To deliver an induction with automatic detection suspended, select the on-screen [Suspend] button, and de-select the [Resume at BURST] checkbox.

Aborting an induction or therapy – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

How to deliver a 50 Hz Burst induction





1. Select Tests > EP Study.
2. Select 50 Hz Burst from the Inductions/Therapies box.
3. If you wish to treat the induced episode with a manual therapy, select [Suspend] to prevent automatic detection.
4. Confirm that the [Resume at BURST] checkbox is selected (for automatic detection and therapy) or is deselected (for manual therapy).
5. Accept the test values displayed on the screen, or choose new test values.
6. Accept the sensing and VF therapy values displayed on the screen, or select [Adjust Permanent...]
   a. Select new sensing and VF therapy values if desired.
   b. Select [PROGRAM].
   c. Select [Close].
7. Press and hold the [50 Hz BURST Press and Hold] button. Release the button to end the induction.
8. If necessary, you can use the [ABORT] button to terminate a therapy in progress.

Details about 50 Hz Burst induction

The 50 Hz Burst pacing protocol is designed to induce VF by delivering VOO pacing pulses to the ventricle with an interval of 20 ms. As long as you press and hold the [50 Hz BURST Press and Hold] button on the programmer screen, the device continues delivering the induction (up to a maximum of 10 seconds).

Because so many paced events are delivered during a 50 Hz Burst induction, the programmer screen or real-time recording strip may display a Marker Buffer Full (ER) symbol. This is normal behavior and should be expected during 50 Hz Burst delivery.

Inducing an arrhythmia with Manual Burst

The Manual Burst induction is designed to induce atrial and ventricular tachyarrhythmias by delivering a set of pacing pulses at a uniform, selectable interval to either the ventricle or the atrium. The amplitude and pulse width of the pulses are also selectable. When performing an atrial Manual Burst induction, you can choose to have the device deliver backup ventricular pacing.

See details about Manual Burst induction on page 334.

Parameters

* Medtronic nominal setting

Chamber – Chamber of the heart where the pacing burst is delivered.	Ventricle*, Atrium
Interval (ms) **–** Pacing interval of the Manual Burst induction.	100, 110, . . ., 600*
Amplitude (V) **–** Voltage of each pulse in the pacing sequence.	0.5, 1, . . ., 4*, 5, 6, 8
Pulse Width (ms) **–** Duration of each pulse in the pacing sequence.	0.03, 0.06, 0.1, 0.2, . . ., 0.5*, 0.6, 0.7, . . ., 1.6
VVI Backup – Enables backup ventricular pacing during an atrial induction.	On, Off*
VVI Backup Pacing Rate (ppm, min^{-1}) **–** Pacing rate for backup pacing.	30, 35, . . ., 60*, . . ., 120

(continued)	* Medtronic nominal setting
VVI Backup Amplitude (V) – Voltage of each backup pacing pulse.[a]	0.5, 1, . . ., 4*, 5, 6
VVI Backup Pulse Width (ms) – Duration of each backup pacing pulse.[a]	0.03, 0.06, 0.1, 0.2, . . ., 0.5*, . . ., 1.6
Resume at BURST – (checkbox) Option to resume detection automatically when the induction is delivered.	Enabled*, Disabled

[a] The default value for this parameter is set according to the permanently programmed settings for bradycardia pacing if the device has been interrogated. Otherwise it defaults to the indicated nominal value.

Considerations

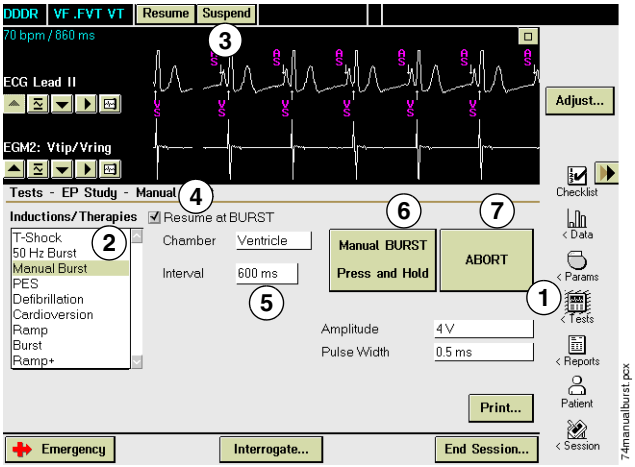
Review the following information before performing the Manual Burst induction.

⚠ **Warning:** Keep an external defibrillator immediately available and on standby.

Detection and auto resume option – If the [Resume at BURST] option is selected, the device automatically resumes tachyarrhythmia detection after the induction. To deliver an induction with automatic detection suspended, select the on-screen [Suspend] button, and de-select the [Resume at BURST] checkbox.

Aborting an induction or therapy – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

How to deliver a Manual Burst induction



1. Select Tests > EP Study.
2. Select Manual Burst from the Inductions/Therapies box.
3. If you wish to treat the induced episode with a manual therapy, select [Suspend] to prevent automatic detection.
4. Confirm that the [Resume at BURST] checkbox is selected (for automatic detection and therapy) or is deselected (for manual therapy).
5. Accept the test values displayed on the screen, or choose new test values.
6. Press and hold the [Manual BURST Press and Hold] button. Release the button to end the induction.
7. If necessary, you can use the [ABORT] button to terminate a therapy in progress.

Details about Manual Burst induction

The Manual Burst induction is designed to induce arrhythmias by delivering AOO or VOO pacing pulses to the atrium or ventricle at a uniform, selectable interval. The amplitude and pulse width of the pulses are also selectable. As long as you press and hold the [Manual BURST Press and Hold] button on the programmer screen, the device continues delivering the induction.

When delivering a Manual Burst induction to the atrium, you can choose to enable VVI Backup pacing, which provides VVI mode pacing to the ventricle during the atrial induction. VVI Backup pacing has separately selectable amplitude, pulse width, and interval values.

Inducing an arrhythmia with PES

Programmed Electrical Stimulation (PES) delivers sequences of premature stimuli to induce atrial and ventricular tachyarrhythmias. The chamber, amplitude, pulse width, and pacing intervals for the induction are all selectable. When performing an atrial PES induction, you can also choose to have the device deliver backup ventricular pacing.

See details about PES induction on page 337.

Parameters

* Medtronic nominal setting

Chamber – Chamber of the heart where the pacing burst is delivered.	Ventricle*, Atrium
#S1 – Number of paced or sensed beats in the initial AAI/VVI sequence.	1, 2, . . . , 8*, . . ., 15
S1S1 (ms) **–** Pacing interval of the initial AAI/VVI sequence.	100, 110, . . ., 600*, . . ., 2000
S1S2 (ms) **–** Pacing interval of the first AOO/VOO pulse.	Off, 100, 110, . . ., 400*, . . ., 600
S2S3 (ms) **–** Pacing interval of the second AOO/VOO pulse.	Off*, 100, 110, . . ., 600
S3S4 (ms) **–** Pacing interval of the third AOO/VOO pulse.	Off*, 100, 110, . . ., 600
Amplitude (V) **–** Voltage of each pulse in the pacing sequence.	0.5, 1, . . ., 4*, 5, 6, 8
Pulse Width (ms) **–** Duration of each pulse in the pacing sequence.	0.03, 0.06, 0.1, 0.2, . . ., 0.5*, 0.6, 0.7, . . ., 1.6
VVI Backup – Enables backup ventricular pacing during an atrial induction.	On, Off*
VVI Backup Pacing Rate (ppm, min^{-1}) **–** Pacing rate for backup pacing.	30, 35, . . ., 60*, . . ., 120
VVI Backup Amplitude (V) **–** Voltage of each backup pacing pulse.[a]	0.5, 1, . . ., 4*, 5, 6

(continued)	* Medtronic nominal setting
VVI Backup Pulse Width (ms) – Duration of each backup pacing pulse.[a]	0.03, 0.06, 0.1, 0.2, . . ., 0.5*, . . ., 1.6
Resume at DELIVER (checkbox) – Option to resume detection automatically when the induction is delivered.	Enabled*, Disabled

[a] The default value for this parameter is set according to the permanently programmed settings for bradycardia pacing if the device has been interrogated. Otherwise it defaults to the indicated nominal value.

Considerations

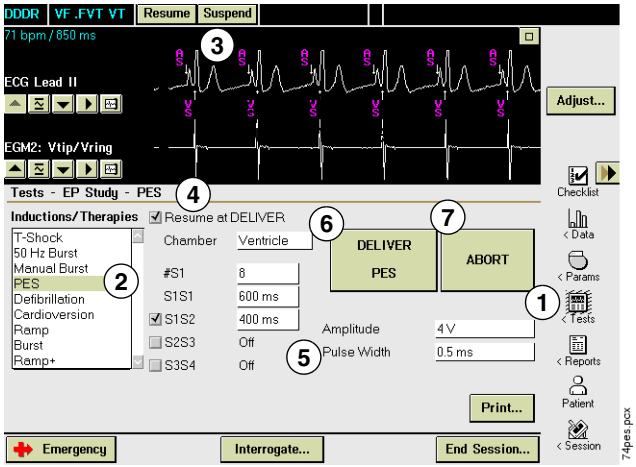
Review the following information before performing the PES induction.

⚠ **Warning:** Keep an external defibrillator immediately available and on standby.

Detection and auto resume option – If the [Resume at DELIVER] option is selected, the device automatically resumes tachyarrhythmia detection after the induction. To deliver an induction with automatic detection suspended, select the on-screen [Suspend] button, and de-select the [Resume at DELIVER] checkbox.

Aborting an induction or therapy – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

How to deliver a PES induction



1. Select Tests > EP Study.
2. Select PES from the Inductions/Therapies box.
3. If you wish to treat the induced episode with a manual therapy, select [Suspend] to prevent automatic detection.
4. Confirm that the [Resume at DELIVER] checkbox is selected (for automatic detection and therapy) or is deselected (for manual therapy).
5. Accept the test values displayed on the screen, or choose new test values.
6. Select the [DELIVER PES] button.
7. If necessary, you can use the [ABORT] button to terminate the induction or any therapy in progress.

Details about PES induction

The PES induction is designed to induce arrhythmias by delivering a selectable number of paced or sensed events in the VVI or AAI pacing mode, followed by up to three premature VOO or AOO paced events. The pulse amplitude and pulse width are programmed in common for all the pulses.

When delivering a PES induction to the atrium, you can choose to enable VVI Backup pacing, which provides VVI mode pacing to the ventricle during the atrial induction. VVI Backup pacing has separately selectable amplitude, pulse width, and interval values.

Delivering a manual therapy

During defibrillation threshold testing at implant, the EP Study screen can provide backup therapy for the induced VF episodes (in addition to the external defibrillator).

At follow-up, manual therapies can be used to assess or manipulate therapy effectiveness as part of chronic care.

See details about manual therapies on page 340.

Parameters for manual defibrillation and cardioversion

* Medtronic nominal setting

Energy (J) – Amount of energy delivered to the heart by the therapy.	0.4, 0.6, . . ., 1.8, 2, 3, . . ., 16, 18,20, . . ., 30*
Pathway – Direction the electrical current flows through the heart.	AX>B* or B>AX

Parameters for manual ATP therapies

* Medtronic nominal setting

General ATP therapy parameters	
Anti-Tachy Pacing Minimum Interval (ms) – Minimum pacing interval for all ATP therapies.	150, 160, . . ., 200*, . . ., 400
V. Amplitude (V) – Voltage of the ventricular pacing pulses delivered during all ATP pacing pulses.	0.5, 1, . . ., 4, 5, 6, 8*
V. Pulse Width (ms) – Duration of the ventricular pacing pulses delivered during all ATP therapies.	0.03, 0.06, 0.1, 0.2, . . ., 1.6*
Ramp therapy parameters	
# Pulses – Number of pulses in the Ramp pacing therapy.	1, 2, . . ., 6*, . . ., 15
%RR Interval – Pacing interval of the first Ramp pulse as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66, . . ., 84, 88, 91, 94, 97*

(continued)	* Medtronic nominal setting
Dec/Pulse (ms) – Pacing interval decrement (in milliseconds) per pulse during a Ramp sequence.	0, 10*, . . ., 40
Burst therapy parameters	
# Pulses – Number of pulses in the Burst pacing therapy.	1, 2, . . ., 6*, . . ., 15
%RR Interval – Pacing interval of the Burst pacing therapy as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66, . . ., 84*, 88, 91, 94, 97
Ramp+ therapy parameters	
# Pulses – Number of pulses in the Ramp+ pacing therapy.	1, 2, 3*, . . ., 15
R-S1 (%RR) – Pacing interval of the first Ramp+ pulse as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66, . . ., 75*, . . ., 84, 88, 91, 94, 97
S1-S2 (%RR) – Pacing interval of the second Ramp+ pulse as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66, 69*, . . ., 84, 88, 91, 94, 97
S2-SN (%RR) – Pacing interval of the remaining Ramp+ pulses as a percentage of the tachycardia cycle length.	50, 53, 56, 59, 63, 66*, . . ., 84, 88, 91, 94, 97

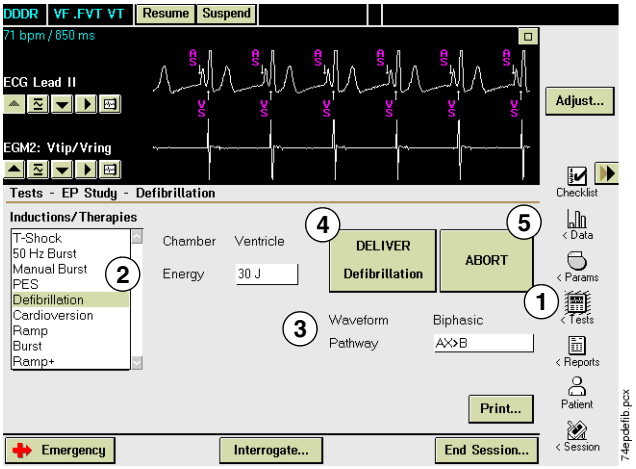
Considerations

Review the following information before delivering a manual therapy.

⚠ **Warning:** Keep an external defibrillator immediately available and on standby.

Aborting an induction or therapy – As a safety precaution, the programmer displays an [ABORT] button that immediately terminates any induction, manual therapy, or automatic therapy in progress. When you deliver a manual therapy, the device automatically aborts any induction or therapy already in progress.

How to deliver a manual therapy



1. Select Tests > EP Study.
2. Select the desired manual therapy from the Inductions/Therapies box.
3. Accept the test values displayed on the screen, or choose new test values.
4. Select [DELIVER Defibrillation].
5. If necessary, you can abort the manual therapy by pressing [ABORT].

Details about manual therapies

Defibrillation

Manual defibrillation therapy charges the device capacitors and delivers a biphasic shock. The device does not attempt to confirm the presence of VF before delivering the shock, which is synchronized to a sensed R-wave if possible. See “Synchronizing defibrillation without confirming VF” on page 114.

Cardioversion

Manual cardioversion therapy charges the capacitors and attempts to synchronize the shock to an arrhythmic ventricular event. If the cardioversion therapy cannot be synchronized, the device aborts the therapy. See “Synchronizing cardioversion after charging” on page 135.

Antitachycardia pacing therapies (ATP)

Manual Ramp, Burst, and Ramp+ therapies deliver one sequence of the selected antitachycardia pacing therapy. For more information about the timing, operation, and programming of ATP therapies, see “Treating VT and FVT with antitachycardia pacing” on page 120.

Key terms

50 Hz Burst – VF induction protocol that delivers a train of pacing pulses into the patient’s heart at 20 millisecond intervals.

antitachycardia pacing (ATP) – therapies for VT or FVT that deliver rapid sequences of pacing pulses to terminate the VT.

auto resume – when the [Resume At DELIVER] or [Resume at BURST] feature is selected, the device automatically resumes detection after delivering an induction.

Manual Burst – tachyarrhythmia induction protocol that delivers a train of pacing pulses at a uniform, programmed interval.

Programmed Electrical Stimulation (PES) – tachyarrhythmia induction protocol that paces the patient’s heart during vulnerable periods in the cardiac cycle to induce atrial or ventricular tachyarrhythmias.

sequence – a set of pacing pulses (for example, in a Burst, Ramp, or Ramp+ ATP therapy).

Suspend – programming command that temporarily deactivates the device detection and therapy functions. Pacing operations are not affected by the [Suspend] command.

telemetry – transmission of data between the device and the programmer by radio waves.

test values – temporary parameters used during EP study operations. Permanent settings are restored automatically once an EP Study operation has ended, the programming head is removed, or the telemetry link is broken.

T-Shock induction – VF induction protocol that delivers a shock synchronized with the ventricular repolarization or T-wave. The device delivers a brief series of rapid paced beats to entrain the heart rhythm, followed by a programmable shock.

Solving system problems

15

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Overview

This chapter describes problems that can occur with the system and suggests some corrective actions. These problems are classified into five different categories:

- Sensing
- Tachyarrhythmia detection
- Tachyarrhythmia therapy
- Bradycardia pacing
- Device status

To solve a system problem, you must follow these steps:

1. Define the problem.

2. Identify the cause of the problem.

3. Perform a corrective action.

The system provides a set of diagnostic tools to help you accomplish these tasks. For more information about the available tools, see Chapter 11, "Using system evaluation tools" on page 249.

Note: The following information is not intended to be an all-inclusive list of system problems. Rather, it is presented as an aid to use in an overall problem-solving strategy.

Solving sensing problems

Sensing is a vital component of nearly all device operations. Problems with detection, therapy, and bradycardia pacing may often be traced to a problem with sensing. Table 15-1 lists some potential problems with sensing, their probable causes, and some corrective actions that may solve those problems.

Table 15-1. Sensing problems

Observed problem	Possible cause	Suggested corrective action
No, or too few normal sense markers displayed in the Live Rhythm Monitor	Lead disconnected from the device connector port	Verify all connections, especially the setscrew contact
	Lead dislodgement	Reposition the lead
	Lead fracture or insulation defect	Replace the lead
	Telemetry link between the device and programmer lost	Reposition the programming head
		Remove any sources of EMI
	Current leakage in the device connector port	Verify that all connections are dry
Double-sensing of ventricular events	T-wave sensing after intrinsic events	Increase sensitivity threshold
		Reposition the lead
	Sensing T-wave or R-wave after paced events	Increase V. Pace Blanking value
Extra ventricular sensed events after atrial pacing	Crosstalk from atrial pacing	Decrease atrial pacing output Increase V. Sensitivity threshold Reposition atrial or ventricular lead
Extra atrial sensed events after ventricular pace or sense	Far-field R-wave sensing or crosstalk from ventricular pacing	Decrease ventricular pacing output Increase A. Sensitivity threshold Reposition atrial or ventricular lead Increase A. Pace Blanking

Table 15-1. Sensing problems (continued)

Observed problem	Possible cause	Suggested corrective action
Atrial sensed events occur simultaneously with ventricular events and are not synchronized with ECG	Atrial lead dislodged into the ventricle	Reposition the atrial lead
Extra ventricular sensed events, especially when the patient moves or the device/lead is manipulated	Poor connection to the device connector port	Verify all connections, especially the setscrew contact
	Lead fracture or insulation defect	Replace the lead
Stored episode shows extra ventricular sensed events, but the Live Rhythm Monitor shows normal sensing	Temporary exposure to an EMI source	Counsel the patient to keep away from sources of EMI
	Poor connection to the device connector port	Verify all connections, especially the setscrew contact
	Lead fracture or insulation defect	Replace the lead

Solving tachyarrhythmia detection problems

Table 15-2 lists some potential problems with tachyarrhythmia detection, their probable causes, and some corrective actions that may solve those problems.

Table 15-2. Tachyarrhythmia detection problems

Observed problem	Possible cause	Suggested corrective action
During a VF episode, VT sense or normal ventricular sensed events occur instead of VF events	VF Interval is too short (VF intervals fall into the VT Detection zone)	Increase the VF Interval
	Undersensing of VF due to decreased amplitude	Decrease the V. Sensitivity threshold
During a VF episode, no VF events are detected	VF Detection is off	Turn VF Detection on
	Detection is suspended	Select [Resume] on the programmer screen
	The VF Interval is shorter than the VF cycle length	Increase the VF Interval
After a VF therapy, a VT episode occurs, but no VT events are detected	VT Detection is suspended for 17 events after VF therapy	None. This is normal operation
During a VT episode, no VT events are detected	VT Detection is off	Turn VT detection on
	Detection is suspended	Select [Resume] on the programmer screen
	The VT Interval is shorter than the VT cycle length	Increase the VT Interval
Occasional normal sensed event markers occur during a VT episode	Small margin between the VT cycle length; slight variations in the interval result in normal senses	Increase the VT Interval
	Stability criterion is on and is too sensitive	Turn Stability off Choose a larger Stability interval

Solving tachyarrhythmia therapy problems

Table 15-3 lists some common problems with therapy, their probable causes, and some corrective actions that may solve those problems.

Table 15-3. Tachyarrhythmia therapy problems

Observed problem	Possible cause	Suggested corrective action
More than one high voltage therapy required, or rescue shock required	Increased DFT due to change in patient's status (new medications, myocardial infarction)	Set the therapy energy level higher, if possible
		Change pathway polarity
		Add a supplementary high voltage electrode
		Titrate drugs, if possible
	Lead dislodgement	Reposition the lead
	Lead fracture or insulation defect	Replace the lead
High voltage therapy reported with high impedance (> 200 ohms) and low delivered energy	The lead system has a short circuit, but the short circuit protection feature interrupted high voltage therapy delivery	Correct short circuit condition, replacing leads as necessary
	Lead disconnected from the device connector port	Verify all connections, especially the setscrew contact
	Lead fracture	Replace the lead
	Active Can is turned off and no lead is connected to the SVC (HVX) port	Turn Active Can on, or implant a supplementary high voltage lead and connect it to the SVC (HVX) port
Programmed ATP therapies not delivered	Smart Mode is on and has disabled an unsuccessful ATP therapy	Choose a different therapy
		Reprogram ATP therapy parameters
	ATP pacing inhibited because the VT cycle length is less than the programmed ATP Minimum interval	Decrease ATP Minimum Interval

Solving bradycardia pacing problems

Table 15-4 lists some potential problems with bradycardia pacing, their probable causes, and some corrective actions that may solve those problems.

Table 15-4. Bradycardia pacing problems

Observed problem	Possible cause	Suggested corrective action
Pacing fails to capture after cardioversion or defibrillation therapy	Temporary increase in pacing threshold after shock	Increase Post-Shock Pacing Amplitude and Pulse Width
High rate pacing without patient activity	Pacemaker-mediated tachycardia (PMT)	Turn PMT Intervention on
		Turn PVC Response on
		Set PVARP to a larger value
	Rate response parameters are too sensitive	Select a less sensitive value for Activity Threshold
		Decrease the Rate Response value
		Choose a pacing mode without rate response
AAI or AAIR paced events sensed as VT or VF events	Loss of A-V synchrony and crosstalk	Choose a different pacing mode
High intrinsic atrial rate but slow ventricular pacing in response	The atrial rate is faster than the 2:1 block rate	Decrease PVARP
		Decrease SAV
		Enable Rate Adaptive AV
		Set PVARP to Varied
	The atrial rate is faster than the Upper Tracking Rate	Increase Upper Tracking Rate

Table 15-4. Bradycardia pacing problems (continued)

Observed problem	Possible cause	Suggested corrective action
High ventricular pacing rate during atrial fibrillation or flutter	The device is pacing the ventricle in response to atrial events	Turn Mode Switch on Set the pacing mode to DDIR or DDI
Atrial paced events are followed immediately by ventricular sense markers (but ECG shows a slow ventricular rate)	Ventricular pacing is inhibited by crosstalk from atrial pacing	Turn V. Safety Pacing on Decrease atrial pacing output Increase V. Sensitivity threshold Reposition atrial or ventricular lead

Responding to device status indicators

The device performs self-diagnostics to identify problems with its critical functions. If it detects a problem, it sets a device status indicator, which appears on the programmer screen during interrogation. Table 15-5 lists the device status indicators, their probable causes, and some suggested actions to take.

Table 15-5. Device status indicators

Device Status Indicator	Possible cause	Suggested corrective action
Electrical Reset occurred	Device memory was corrupted by EMI, electrocautery, external defibrillation, or some other environmental effect	Perform the Electrical Reset recovery procedure
Charge Circuit Timeout	A single long charging period has occurred	Replace the device immediately
Charge Circuit Inactive	Three consecutive long charging periods have occurred.	Replace the device immediately
Quick Look screen displays an ERI indicator	The device battery voltage is lower than the ERI threshold (2.62 V)	Schedule an appointment to replace the device
	A long charging period (> 16 s) has triggered the ERI indicator	Replace the device immediately
Quick Look screen displays an EOL indicator	Three months have passed since the device reached ERI[a]	Replace the device immediately

[a] EOL may be indicated before the end of three months if actual battery usage exceeds the post-ERI operating conditions (see “Post-ERI conditions” on page 9).

Key terms

activity threshold – programmable parameter that defines the minimum level of patient body motion that causes a rate response in rate responsive pacing modes.

blanking period – time interval after each pacing pulse, sensed event, or shock, when no sensing can occur.

crosstalk – the sensing of a pacing stimulus delivered in the opposite chamber.

Decision Channel telemetry – annotations to stored and telemetered EGMs, documenting some details of dual chamber tachyarrhythmia detection.

electromagnetic interference (EMI) – radiated or conducted energy, either electrical or magnetic, that can interfere with the device sensing operation in some circumstances.

electrical reset – automatic device operation to recover from a disruption in device memory and control circuitry. Programmed parameters may be set to electrical reset values.[1] This operation triggers a device status indicator and an automatic Patient Alert tone.

Live Rhythm Monitor – configurable programmer display of telemetered ECG, Marker Channel, and EGM waveforms on one screen or a partial-screen window.

pacemaker-mediated tachycardia (PMT) – paced rhythm that results when the device senses and tracks retrograde P-waves in DDD or DDDR mode. This retrograde conduction and atrial tracking repeats itself to produce an inappropriately rapid paced rhythm.

PVC (premature ventricular contraction) – a sensed ventricular event that directly follows any other ventricular event, with no atrial event between them.

[1] See Appendix B, "Device Parameters" on page 367 for reset settings.

PVC Response – detects a PVC and responds by extending the PVARP to 400 ms (if the currently programmed or Sensor-Varied PVARP is less than 400 ms).

Rate Adaptive AV – dual chamber pacing feature that shortens the AV interval as the heart rate increases.

Resume – programming command that reinstates automatic tachyarrhythmia detection.

sensed event – electrical activity across the sensing electrodes that exceeds the programmed sensitivity threshold.

sensitivity – degree to which the sensing circuitry is responsive to intracardiac signals.

Smart Mode – optional feature available for the first four VT and FVT therapies that disables an ATP therapy if it is unsuccessful in four consecutive episodes.

Stability criterion – programmable VT detection criterion that allows the device to screen out irregular ventricular rhythms or unstable VTs (for example, those caused by the conduction of atrial fibrillation or flutter).

Suspend – programming command that temporarily deactivates the tachyarrhythmia detection functions.

undersensing – failure to sense the P-wave or R-wave. Undersensing can cause inappropriate bradycardia pacing or a failure to detect tachyarrhythmia.

VF Interval – (also called FDI) programmable interval used to define the VF detection zone. V-V intervals shorter than the VF Interval are counted as VF events.

VT Interval – (also called TDI) programmable interval used to define the VT detection zone. V-V intervals shorter than the VT Interval but greater than or equal to the VF and/or FVT Interval are counted as VT events.

Part V

Appendices

Warnings and precautions

A

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Device implantation and ICD programming 359

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Explant and disposal 363

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General warnings

Avoiding shock during handling – Program tachyarrhythmia detection Off during surgical implant and explant or post-mortem procedures because the ICD can deliver a serious shock if you touch the defibrillation terminals while the ICD is charged.

Electrical isolation during implantation – Do not permit the patient to contact grounded equipment, which could produce hazardous leakage current during implantation. Resulting arrhythmia induction could result in the patient's death.

Lead system – Do not use another manufacturer's lead system without demonstrated compatibility, as undersensing of cardiac activity and failure to deliver necessary therapy could result.

Resuscitation availability – Do not perform ICD testing unless an external defibrillator and medical personnel skilled in cardiopulmonary resuscitation (CPR) are readily available.

Storage and handling

Checking and opening the package – Before opening the sterile package tray, visually check for any signs of damage that might invalidate the sterility of its contents. Return damaged packages to the manufacturer. For instructions on opening the sterile package, see the diagram inside the lid of the shelf box.

Device storage – Store the device in a clean area, away from magnets, kits containing magnets, and sources of electromagnetic interference to avoid device damage.

Dropped device – Do not implant the device if it has been dropped on a hard surface from a height of 30 cm (12 inches) or more after removal from its packaging.

Equilibration – Allow the device to reach room temperature before programming or implanting because rapid temperature changes could affect initial device function.

Temperature limits – Store and transport the package between -18 °C and 55 °C (0 °F to 131 °F).

“Use By” Date – Do not implant the device after the “Use By” date because the battery longevity could be reduced.

Resterilization

Medtronic has sterilized the package contents with ethylene oxide prior to shipment. Resterilization is necessary only if the seal on the sterile package is broken. (Resterilization does not affect the “Use By” date.) If necessary, resterilize with ethylene oxide using a validated sterilization process, observing the following precautions:

- Do not resterilize using an autoclave, gamma radiation, organic cleaning agents (such as alcohol, acetone, etc.), or ultrasonic cleaners.
- Do not exceed 55 °C (131 °F) or 103 kPa (15 psi) when sterilizing.
- Do not resterilize the device more than twice.

Device implantation and ICD programming

Accessories – The device may be used only with accessories, parts subject to wear and disposable items, of which the completely safe use on safety and technical grounds has been demonstrated by a testing agency approved for the testing of the device. Use only Medtronic programmers and application software to communicate with the device.

Battery depletion – Battery depletion will eventually cause the device to cease functioning and should be carefully monitored. Cardioversion and defibrillation are high energy therapies and may quickly deplete the battery and shorten the device longevity. An excessive number of charging cycles will also shorten the longevity.

Charge Circuit Timeout or Charge Circuit Inactive – Replace the device immediately if the programmer displays a Charge Circuit Timeout or Charge Circuit Inactive message.

Concurrent pacemaker use – If a pacemaker is used concurrently with the ICD, verify that the ICD will not sense the pacemaker output pulses. Program the pacemaker so that pacing pulses are delivered at intervals longer than the ICD tachyarrhythmia detection intervals.

End of Life (EOL) indicator – Replace the device immediately if the programmer displays an End of Life (EOL) symbol.

Higher energy on the output capacitor – A higher than programmed energy can be delivered to the patient when the device has been previously charged to a higher energy and the energy is still present on the output capacitors.

Lead compatibility – Do not use another manufacturer's lead system without demonstrated compatibility as undersensing of cardiac activity and failure to deliver necessary therapy could result.

Medical treatment influencing device operation – The electrophysiological characteristics of a patient's heart can alter over time and the programmed therapies may become ineffective and even dangerous to the patient. This is especially to be considered when the patient's drug treatment has changed.

Pacemaker dependent patients – Always program Ventricular Safety Pacing (VSP) On for pacemaker dependent patients.

Programmers – Use only Medtronic programers, application software, and accessories to communicate with the device.

Use of a magnet – Positioning a magnet over the device suspends detection and treatment but does not alter bradycardia therapy. The programming head contains a magnet that can suspend detection, but if telemetry between the device and programmer is established, detection is not suspended.

Lead evaluation and lead connection

- Use only ethylene oxide for lead resterilization. Do not resterilize more than one time.
- Do not tie a ligature directly to the lead body, tie it too tightly, or otherwise create excessive strain at the insertion site as this can damage the lead.
- Do not immerse leads in mineral oil, silicone oil, or any other liquid.
- Do not grip the lead with surgical instruments.
- Do not use excessive force or surgical instruments to insert a stylet into a lead.
- Use the same polarity evaluated during testing when connecting the leads to the ICD to ensure defibrillation effectiveness.
- Do not fold, alter, or remove any portion of the patch because doing so could compromise electrode function or longevity.
- Do not use ventricular transvenous leads in patients with tricuspid valve disease or a mechanical prosthetic tricuspid valve. Use with caution in patients with a bioprosthetic valve.
- Use the correct suture sleeve (when needed) for each lead to immobilize the lead and protect it against damage from ligatures.
- Ensure that the defibrillation lead impedance is greater than 20 ohms. An impedance below 20 ohms could damage the ICD.
- Do not kink the leads. Kinking leads can cause additional stress on the leads, possibly resulting in lead fracture.
- Do not suture directly over the lead body as this may cause structural damage. Use the lead anchoring sleeve to secure the lead lateral to the venous entry site.

- Lead or Active Can electrodes in electrical contact during a high voltage therapy could cause current to bypass the heart, possibly damaging the ICD and leads. While the ICD is connected to the leads, make sure that no therapeutic electrodes, stylets, or guidewires are touching or connected by an accessory low impedance conductive pathway. Move objects made from conductive materials (e.g., an implanted guidewire) well away from all electrodes before a high voltage shock is delivered.
- Make sure to cap any pacing lead that is abandoned rather than removed to ensure that the lead does not become a pathway for currents to or from the heart.
- Make sure to plug any unused lead port in the device to protect the ICD.
- Refer to the lead technical manuals for specific instructions and precautions about lead handling.

Follow-up testing

- Ensure that an external defibrillator and medical personnel skilled in cardiopulmonary resuscitation (CPR) are present during post-implant ICD testing should the patient require external rescue.
- Be aware that changes in the patient's condition, drug regimen, and other factors may change the defibrillation threshold (DFT), which may result in nonconversion of the arrhythmia post-operatively. Successful conversion of ventricular fibrillation or ventricular tachycardia during testing is no assurance that conversion will occur post-operatively.

Explant and disposal

- Interrogate the ICD, program VF and VT Detection Off, and disable ICD functions prior to explanting, cleaning, or shipping the ICD to prevent unwanted shocks.
- Explant the ICD postmortem. In some countries, explanting battery-operated implantable devices is mandatory because of environmental concerns; please check your local regulations. In addition, if subjected to incineration or cremation temperatures, the device could explode.
- Medtronic implantable devices are intended for single use only. Do not resterilize and re-implant explanted devices.
- Please return explanted devices to Medtronic for analysis and disposal. See the back cover for mailing addresses.

Medical therapy hazards

Diathermy – People with metal implants such as pacemakers, implantable cardioverter defibrillators (ICDs), and accompanying leads should not receive diathermy treatment. The interaction between the implant and diathermy can cause tissue damage, fibrillation, or damage to the device components, which could result in serious injury, loss of therapy, and/or the need to reprogram or replace the device.

Electrosurgical cautery – Electrosurgical cautery could induce ventricular arrhythmias and/or fibrillation or may cause implanted device malfunction or damage. If electrocautery cannot be avoided, observe the following precautions to minimize complications:

- Have temporary pacing and defibrillation equipment available.
- Program the implanted device to the DOO mode.
- Suspend tachyarrhythmia detection using a magnet, or turn detection Off using the programmer.
- Avoid direct contact with the implanted device or leads. If unipolar cautery is used, position the ground plate so that the current pathway does not pass through or near the implanted device system (minimum of 15 cm [six inches]).

- Use short, intermittent, and irregular bursts at the lowest feasible energy levels.
- Use a bipolar electrocautery system, where possible.

External defibrillation – External defibrillation may damage the implanted device or may result in temporary and/or permanent myocardial damage at the electrode tissue interface as well as temporary or permanent elevated pacing thresholds. Attempt to minimize the voltage potential across the device and leads by following these precautions:

- Use the lowest clinically appropriate energy output.
- Position defibrillation patches or paddles as far from the device as possible (minimum of 15 cm [6 inches]) and perpendicular to the implanted device-lead system.

  If an external defibrillation was delivered within 15 cm (6 inches) of the device, contact your Medtronic representative.

High-energy radiation – Diagnostic X-ray and fluoroscopic radiation should not affect the device; however, high-energy radiation sources such as cobalt 60 or gamma radiation should not be directed at the device. If a patient requires radiation therapy in the vicinity of the device, place lead shielding over the implant site as a precaution against radiation damage.

Lithotripsy – Lithotripsy may permanently damage the implanted device if it is at the focal point of the lithotripsy beam. If lithotripsy must be used, keep the focal point of the lithotripsy beam at least 2.5 to 5 cm (one to two inches) from the implanted device and temporarily turn off ICD therapies during the lithotripsy procedure.

Magnetic resonance imaging (MRI) – Magnetic resonance imaging (MRI) should not be used on patients who have an implanted cardiac device because of the potential damage to the implanted device.

Radio frequency (RF) ablation – Radio frequency ablation procedure in a patient with an implanted cardiac device could cause implanted device malfunction or damage. To minimize the risks from radio frequency ablation, follow these guidelines:

- Have temporary pacing and defibrillation equipment available.

- Program the implanted device to the DOO mode.
- Suspend tachyarrhythmia detection using a magnet, or turn detection Off using the programmer.
- Avoid direct contact between the ablation catheter and the implanted lead or device.
- Position the ground plate so that the current pathway does not pass through or near the implanted device system (minimum of 15 cm [six inches]).

Therapeutic ultrasound – Exposure of the device to therapeutic ultrasound is not recommended as it may permanently damage the device. Damage to the device may affect therapy.

Home and occupational environments

Cellular phones – Marquis DR ICDs contain a filter that prevents most cellular phone transmissions from interacting with device operation. To further minimize the possibility of interaction, observe the following cautions:

- Maintain a minimum separation of 15 cm (six inches) between the device and the hand-held telephone handset.
- Maintain a minimum separation of 30 cm (twelve inches) between the device and any antenna transmitting above three watts.
- Hold the handset to the ear furthest from the implanted device.
- Do not carry the handset within 15 cm (six inches) of the implanted device (even if the handset is not on).

The Marquis DR has been tested using the ANSI/AAMI PC-69 standard to ensure compatibility with hand-held wireless and PCS phones and other similar power hand-held transmitters. These transmission technologies represent the majority of the cellular telephones in use worldwide. The circuitry of this device, when operating under nominal conditions, has been designed to eliminate any significant effects from the cellular telephones.

Commercial electrical equipment – Commercial electrical equipment such as arc welders, induction furnaces, or resistance welders could generate enough EMI to interfere with device operation if approached too closely.

Communication equipment – Communication equipment such as microwave transmitters, line power amplifiers, or high power amateur transmitters could generate enough EMI to interfere with device operation if approached too closely.

Electric or magnetic interference (EMI) – Patients should be directed to avoid devices that generate strong electric or magnetic interference (EMI). EMI could cause malfunction or damage resulting in prevention of proper programming, or confirmation, non-detection or delivery of unneeded therapy. Moving away from the interference source, or turning it off, usually allows the device to return to its normal mode of operation.

Electronic Article Surveillance – Electronic Article Surveillance equipment such as retail theft prevention systems may interact with the implanted device. Patients should be advised to walk directly through and not to remain near an EAS system longer than is necessary.

High voltage lines – High voltage power transmission lines could generate enough EMI to interfere with device operation if approached too closely.

Home appliances – Home appliances that are in good working order and properly grounded do not usually produce enough EMI to interfere with device operation. There are reports of ICD disturbances caused by electrical hand tools or electric razors used directly over the implant site.

Static magnetic fields – Patients should avoid equipment or situations where they would be exposed to static magnetic fields (greater than 10 gauss or 1 millitesla). Such magnetic fields could suspend detection of arrhythmias. Examples of magnetic sources that could interfere with normal device operation include stereo speakers, bingo wand, extractor wand, magnetic badges, or magnetic therapy products.

Device Parameters

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Emergency settings

Table B-1 Emergency settings

Parameter	Selectable values	Default
Defibrillation		
Energy (J)	10, 11, . . ., 16,18, 20, . . ., 30	30
Pathway[a]	AX>B	---
Cardioversion		
Energy (J)	0.4, 0.6, . . ., 2, 3, 4, . . ., 16, 18, 20, . . ., 30	30
Pathway[a]	AX>B	---
Fixed burst		
Pacing Interval (ms)	100, 110, . . ., 600	350
V. Pulse Amplitude[b] (V)	8	---
V. Pulse Width (ms)	1.6	---
VVI Pacing		
Pacing Mode	VVI	---
Lower Rate (ppm, min^{-1})	70	---
V. Sensitivity/A.Sensitivity	As programmed	---
V. Pulse Amplitude[b] (V)	6 V	---
V. Pulse Width (ms)	1.6 ms	---
V. Pace Blanking (ms)	240 ms	---
Hysteresis	Off	---
V. Rate Stabilization	Off	---

[a] If Active Can is Off, the HVA (Can) electrode is not used as part of the high voltage delivery pathway.

[b] Peak pacing amplitude. When tested per Cenelec standard 45502-2-1, the measured amplitude A depends upon the programmed amplitude A_p and programmed pulse width W_p:$A=A_p \times [0.9 - (W_p \times 0.145\ ms^{-1})]$.

Detection parameters

Table B-2 Tachyarrhythmia detection parameters

Parameter	Programmable values	Shipped	Nominal	Reset
VF Detection Enable	On, Off	Off	On	On
VF Interval (ms)[a]	240, 250, . . . , 400	320	320	320
VF Initial NID	12/16, 18/24, 24/32, 30/40, 45/60, 60/80, 75/100, 90/120, 105/140, 120/160	18/24	18/24	18/24
VF Redetect NID	6/8, 9/12, 12/16, 18/24, 21/28, 24/32, 27/36, 30/40	12/16	12/16	12/16
FVT Detection Enable	Off, via VF, via VT	Off	Off	Off
FVT Interval (ms)[a]	200, 210, . . ., 600	---	---	---
VT Detection Enable	On, Off, Monitor	Off	Off	Off
VT Interval (ms)[a]	280, 290, . . ., 600	400	400	400
VT Initial NID	12, 16, . . ., 52, 76, 100	16	16	16
VT Redetect NID	4, 8, 12, . . ., 52	12	12	12
Stability (ms)[a]	Off, 30, 40, . . ., 100	Off	Off	Off
AFib / AFlutter[b,c]	On, Off	Off	Off	Off
Sinus Tach[b,c]	On, Off	Off	Off	Off
1:1 VT-ST Boundary (%)	35, 50, 66, 75, 85	50	50	50
Other 1:1 SVTs[b]	On, Off	Off	Off	Off
SVT Limit (ms)[a]	240, 250, . . ., 600	320	320	320
High Rate Timeout (min)	Off, 0.75, 1, 1.25, 1.5, 2, 2.5, . . ., 5, 6, 7, . . ., 20, 22, 24, . . ., 30	Off	Off	Off
High Rate Timeout Therapy	Zone Appropriate, Skip to VF Therapy	Zone Appropriate		

Table B-2 Tachyarrhythmia detection parameters (continued)

Parameter	Programmable values	Shipped	Nominal	Reset
A. Sensitivity (mV)[d,e]	0.15, 0.3, 0.45, 0.6, 0.9, 1.2, 1.5, 2.1	0.3	0.3	0.3
V. Sensitivity (mV)[d,e]	0.15, 0.3, 0.45, 0.6, 0.9, 1.2	0.3	0.3	0.3

[a] The measured intervals are truncated to a 10 ms multiple (e.g., 457 ms becomes 450 ms). The device uses this truncated interval value when applying the programmed criteria and calculating interval averages.

[b] Double tachycardia (i.e. “VF/FVT/VT plus SVT”) detection is automatically enabled when any Dual Chamber SVT criterion is enabled.

[c] The device is shipped with the Sinus Tach and A.Fib / A.Flutter criteria off. However, when VT Detection is set to On or Monitor, these parameters are set to On.

[d] With a 40 ms sine^2 waveform (ventricular sensitivity) or a 20 ms sine^2 waveform (atrial sensitivity). When using the Cenelec waveform, the rated sensing threshold value will be 1.5 times (ventricular) or 1.4 times (atrial) the rated sine^2 sensing threshold.

[e] This setting applies to all sensing in this chamber for both tachyarrhythmia detection and bradycardia pacing operations.

Therapy parameters

Table B-3 Tachyarrhythmia therapy parameters

Parameter	Programmable values	Shipped	Nominal	Reset
VF Therapy Status[a]	On, Off	On	On	On
VT Therapy Status[a]	On, Off	None	On	None
VT Therapy Type[a]	CV, Burst, Ramp, Ramp+	---	---	---
FVT Therapy Status[a]	On, Off	None	On	None
FVT Therapy Type[a]	CV, Burst, Ramp, Ramp+	---	---	---
VF therapy (defibrillation) parameters				
Energy (J)[b,c]	0.4, 0.6, . . ., 1.8, 2, 3, . . ., 16, 18, 20, . . ., 30	30	30	30
Pathway	AX>B, B>AX	AX>B	AX>B	AX>B
Confirm VF after initial detection?[a,d]	Yes, No	Yes	Yes	Yes
Cardioversion parameters				
Energy (J)[c]	0.4, 0.6, . . ., 1.8, 2, 3, . . ., 16, 18, 20, . . ., 30	---	30	---
Pathway	AX>B, B>AX	---	AX>B	---
Burst therapy parameters				
Initial # Pulses	1, 2, . . ., 15	---	6[e]	---
R-S1 Interval (% R-R)	50, 53, 56, 59, 63, 66, . . ., 84, 88, 91, 94, 97	---	84[e]	---
Interval Decrement[a] (ms)	0, 10, . . ., 40	---	10	---
# Sequences[a]	1, 2, 3, . . ., 10	---	3[e]	---
Smart Mode[a,f]	On, Off	---	Off	---
Ramp therapy parameters				
Initial # Pulses	1, 2, . . ., 15	---	8[g]	---
R-S1 Interval (% R-R)	50, 53, 56, 59, 63, 66, . . ., 84, 88, 91, 94, 97	---	91[h]	---
Interval Decrement (ms)	0, 10, . . ., 40	---	10	---
# Sequences[a]	1, 2, . . ., 10	---	3	---
Smart Mode[a,f]	On, Off	---	Off	---

Table B-3 Tachyarrhythmia therapy parameters (continued)

Parameter	Programmable values	Shipped	Nominal	Reset
Ramp+ therapy parameters				
Initial # Pulses	1, 2, . . ., 15	---	3	---
R-S1 Interval (% R-R)	50, 53, 56, 59, 63, 66, . . ., 84, 88, 91, 94, 97	---	75	---
S1-S2 Interval (% R-R)	50, 53, 56, 59, 63, 66, . . ., 84, 88, 91, 94, 97	---	69	---
S2-SN Interval (% R-R)	50, 53, 56, 59, 63, 66, . . ., 84, 88, 91, 94, 97	---	66	---
# Sequences[a]	1, 2, . . ., 10	---	5	---
Smart Mode[a,f]	On, Off	---	Off	---
Shared therapy parameters				
Progressive Episode Therapies[a]	On, Off	Off	Off	Off
Active Can	On, Off	On	On	On
V. Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	1.6	1.6	1.6
V. Amplitude (V)[i]	0.5, 1, . . ., 4, 5, 6, 8	8	8	8
V. Pace Blanking (ms)	150, 160, . . ., 440	240	240	240
ATP Minimum Interval (ms)	150, 160, . . ., 400	200	200	200

[a] This parameter does not apply to manual therapies.

[b] For automatic therapy 3, 4, 5, or 6, energy must be at least 10 joules.

[c] Delivered energy based on a biphasic pulse into a 75 ohm load. For energy less than 1 joule, tolerance is ± 0.25 J.

[d] Applies only to the first VF therapy that is programmed On.

[e] FVT Burst therapies have the following Medtronic nominal values: Initial # Pulses is 8, R-S1 Interval is 88%, and # Sequences is 1.

[f] Smart Mode is only available for Therapies 1, 2, 3, and 4.

[g] The nominal Initial # of Pulses for manual ramp therapy is 6.

[h] The nominal R-S1 Interval for manual ramp therapy is 97%.

[i] Peak pacing amplitude. When tested per Cenelec standard 45502-2-1, the measured amplitude A depends upon the programmed amplitude A_p and programmed pulse width W_p:$A=A_p \times [0.9 - (W_p \times 0.145\ ms^{-1})]$.

Bradycardia pacing parameters

Table B-4 Bradycardia pacing parameters

Parameter	Programmable values	Shipped	Nominal	Reset
Pacing Mode	DDDR, DDD, DDIR, DDI, AAIR, AAI, VVIR, VVI, DOO, VOO, ODO	DDD	DDDR	VVI
Lower Rate (ppm, min^{-1})	30, 35, 40, . . ., 60, 70, 75, . . ., 150	60	60	65
Upper Tracking Rate (ppm, min^{-1})	80, 85, . . ., 150	120	120	120
Upper Sensor Rate (ppm, min^{-1})	80, 85, . . ., 150	120	120	120
Paced AV (ms)	30, 40, . . ., 350	180	180	180
Sensed AV (ms)	30, 40, . . ., 350	150	150	150
PVARP (ms)	Varied, 150, 160, . . ., 500	310	310	310
A. Refractory (ms)	150, 160, . . ., 500	310	310	310
PVAB (ms)[a]	100, 110, . . ., 310	150	150	150
A. Amplitude (V)[b]	0.5, 1, . . ., 3, 3.5, 4, 5, 6	3	3	4
A. Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	0.4	0.4	0.4
A. Sensitivity (mV)[c,d]	0.15, 0.3, 0.45, 0.6, 0.9, 1.2, 1.5, 2.1	0.3	0.3	0.3
A. Pace Blanking (ms)	150, 160, . . ., 250	200	200	240
V. Amplitude (V)[b]	0.5, 1, . . ., 3, 3.5, 4, 5, 6	3	3	6
V. Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	0.4	0.4	1.6
V. Sensitivity (mV)[c,d]	0.15, 0.3, 0.45, 0.6, 0.9, 1.2	0.3	0.3	0.3
V. Pace Blanking (ms)	150, 160, . . ., 440	200	200	240
Post-Shock Pacing Parameters				
A. Amplitude (V)[b]	0.5, 1, 1.5, . . ., 4, 5, 6, 8	4	4	4
A. Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	1.6	1.6	1.6
V. Amplitude (V)[b]	0.5, 1, 1.5, . . ., 4, 5, 6, 8	6	6	6
V. Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	1.6	1.6	1.6

Table B-4 Bradycardia pacing parameters (continued)

Parameter	Programmable values	Shipped	Nominal	Reset
Mode Switch Parameters				
Enable	On, Off	Off	On	Off
A. Detect Rate (bpm, min^{-1})	120, 125, . . ., 175	175	175	175
Rate Response Pacing Parameters				
Rate Response	1, 2, . . ., 10	7	7	7
Activity Threshold	Low, Medium Low, Medium High, High	Medium Low	Medium Low	Medium Low
Activity Acceleration (sec.)	15, 30, 60	30	30	30
Activity Deceleration (min.)	Exercise, 2.5, 5, 10	5	5	5
Rate Adaptive AV Parameters				
Enable	On, Off	On	On	On
Start Rate (bpm, min^{-1})	50, 55, . . ., 145	60	60	60
Stop Rate (bpm, min^{-1})	55, 60, . . ., 150	120	120	120
Minimum PAV (ms)	30, 40, . . ., 350	140	140	140
Minimum SAV (ms)	30, 40, . . ., 350	110	110	110

Table B-4 Bradycardia pacing parameters (continued)

Parameter	Programmable values	Shipped	Nominal	Reset
Additional Pacing Features				
Non-Comp Atrial Pacing				
Enable	On, Off	On	On	On
Interval (ms)	200, 250, . . ., 400	300	300	300
Single Chamber Hysteresis (bpm, min^{-1})	Off, 30, 40, . . ., 80	Off	Off	Off
V. Rate Stabilization				
V. Rate Stabilization	On, Off	Off	Off	Off
V. Rate Stabilization Minimum Interval (ms)	500, 550, . . ., 900	500	500	500
V. Rate Stabilization Interval Increment (ms)	50, 60, . . ., 400	150	150	150
PMT Intervention	On, Off	Off	Off	Off
PVC Response	On, Off	On	On	On
V. Safety Pacing	On, Off	On	On	On

[a] PVAB is the minimum value that PVARP is shortened to, under sensor-varied PVARP operation. Atrial events that fall within the PVAB are ignored by the Mode Switch, NCAP, PVC Response, and PMT Intervention features.

[b] Peak pacing amplitude. When tested per Cenelec standard 45502-2-1, the measured amplitude A depends upon the programmed amplitude A_p and programmed pulse width W_p: $A = A_p \times [0.9 - (W_p \times 0.145\ ms^{-1})]$.

[c] With a 40 ms $sine^2$ waveform (ventricular sensitivity) or a 20 ms $sine^2$ waveform (atrial sensitivity). When using the Cenelec waveform, the rated sensing threshold value will be 1.5 times (ventricular) or 1.4 times (atrial) the rated $sine^2$ sensing threshold.

[d] This setting applies to all sensing in this chamber, for both tachyarrhythmia detection and bradycardia pacing operations.

System maintenance parameters

Table B-5 System maintenance parameters

Parameter	Programmable values	Shipped	Nominal	Reset
Automatic Capacitor Formation Interval (months)	Auto, 1, 2, . . ., 6	Auto[a]	Auto	Auto
Patient Alert time	(enter time in hours and minutes)	8:00 am	---	8:00 am
Impedance patient alerts				
A. Pacing lead	On, Off	Off	On	Off
Minimum Threshold (ohms)	200, 300, 400, 500	200	200	200
Maximum Threshold (ohms)	1000, 1500, 2000, 3000	3000	3000	3000
V. Pacing lead	On, Off	Off	On	Off
Minimum Threshold (ohms)	200, 300, 400, 500	200	200	200
Maximum Threshold (ohms)	1000, 1500, 2000, 3000	3000	3000	3000
V. Defibrillation lead	On, Off	Off	On	Off
Minimum Threshold (ohms)	20, 30, 40, 50	20	20	20
Maximum Threshold (ohms)	100, 130, 160, 200	200	200	200
SVC (HVX) Defibrillation lead	On, Off	Off	On	Off
Minimum Threshold (ohms)	20, 30, 40, 50	20	20	20
Maximum Threshold (ohms)	100, 130, 160, 200	200	200	200
Lead impedance alert urgency	Low, High	---	Low	---
Low Battery Voltage ERI patient alert	Off, On-Low, On-High	Off	On-Low	Off
Excessive Charge Time ERI patient alert	Off, On-Low, On-High	Off	On-Low	Off
Number of Shocks Delivered in an Episode patient alert	Off, On-Low, On-High	Off	On-Low	Off
Number of Shocks threshold	1, 2, . . ., 6	3	3	3
All Therapies in a Zone Exhausted for an Episode patient alert	Off, On-Low, On-High	Off	On-Low	Off
VF Detection/Therapy Off[b]	Off, On-High	On-High	On-High	On-High

[a] Automatic Capacitor Formation is disabled until VF Detection is set to On for the first time.

[b] When this alert is turned on, it does not sound when a magnet is applied unless VF detection or more than two VF therapies are turned off.

Data collection parameters

Table B-6 Data collection parameters

Parameter	Programmable values	Shipped	Nominal	Reset
EGM Channel 1 Source	Can to HVB, Can to Vring, Can to Aring, Vtip to HVB, Vtip to Vring, Atip to Vring, Atip to Aring, Can to HVX,[a] HVB to HVX[a]	Atip to Aring	Atip to Aring	Atip to Aring
EGM Channel 1 Range (mV)	± 2, ± 4, ± 8, ± 16	± 8	± 8	± 8
EGM Channel 2 Source	Can to HVB, Can to Vring, Vtip to HVB, Vtip to Vring, Can to HVX,[a] HVB to HVX[a]	Vtip to Vring	Vtip to Vring	Vtip to Vring
EGM Channel 2 Range (mV)	± 2, ± 4, ± 8, ± 16	± 8	± 8	± 8
Store EGM Channel 1?[b]	Yes, No	Yes	Yes	Yes
Store EGM Channel 2	Yes (fixed)	---	---	---
Store EGM during charging?	Yes, No	Yes	Yes	Yes
Store EGM before tachycardia starts?	Yes, No	No	No	No
Device Date/Time[c]	(enter time and date)	---	---	---
Premature Event Threshold (%)	56, 59, 62, 66, 69, . . ., 84, 88, 91, 94, 97	69	69	69
Holter Telemetry Duration (hours)	Off, 0.5, 1, 2, 4, 8, 16, 24, 36, 46	Off	Off	Off

[a] An SVC lead must be present for this configuration.

[b] Both channels are available as real-time telemetered signals, regardless of this setting.

[c] The time stamp on episode records and other stored data is determined by the device's date/time clock.

System test and EP study parameters

Table B-7 System test and EP study parameters

Parameter	Selectable values	Default
Pacing threshold test parameters		
Test Type	Pulse Width - Auto Dec, Manual	Pulse Width - Auto Dec
Chamber	Atrium, Ventricle	Ventricle
Mode (atrial test)[a]	AAI, DDI, DDD	DDD[b]
Mode (ventricular test)[a]	VVI, DDI, DDD	VVI[b]
Lower Rate (ppm, min^{-1})	30, 35, . . .,60, 70, 75, . . .,150[c]	90
AV Delay (ms)	30, 40, . . ., 350	150[b]
V. Amplitude (V)[d]	0.5, 1, . . ., 4, 5, 6	3[b]
V. Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	0.4[b]
V. Pace Blanking (ms)	150, 160, . . ., 440	200[b]
A. Amplitude (V)[d]	0.5, 1, . . ., 4, 5, 6	3[b]
A. Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	0.4[b]
A. Pace Blanking (ms)	150, 160, . . ., 250	200[b]
PVARP (ms)	150, 160, . . ., 500	310[b]
EGM Amplitude test parameters		
Mode[a]	ODO, AAI, VVI, DDI, DDD	---
AV Delay (ms)	30, 40, . . ., 350	250
Lower Rate (ppm, min^{-1})	30, 35, . . .,60, 70, 75, . . .,120[c]	---

Table B-7 System test and EP study parameters (continued)

Parameter	Selectable values	Default
T-Shock induction parameters		
#S1	2, 3, . . ., 8	8
S1S1 (ms)	300, 310, . . ., 2000	400
Delay (ms)	50, 60, . . ., 600	310
Energy (J)[e]	0.4, 0.6, . . ., 1.8, 2, 3, . . ., 16, 18, 20, . . ., 30	0.6
Pathway	AX>B, B>AX	AX>B
Waveform	Monophasic, Biphasic	Monophasic
Pulse Amplitude (V)[d]	8 V (fixed)	---
Pulse Width (ms)	1.6 ms (fixed)	---
Enable	Enabled, Disabled	Disabled
Resume at Deliver	Enabled, Disabled	Enabled
50 Hz Burst Induction Parameters		
Interval (ms)	20 ms (fixed)	---
Pulse Amplitude (V)[d]	0.5, 1, . . ., 4, 5, 6, 8	8
Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	1.6
Resume at Burst	Enabled, Disabled	Enabled
Manual Burst Induction Parameters		
Chamber	Ventricle, Atrium	Ventricle
Interval (ms)	100, 110, . . ., 600	600
Pulse Amplitude (V)[d]	0.5, 1, . . ., 4, 5, 6, 8	4
Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	0.5
Resume at Burst	Enabled, Disabled	Enabled
VVI Backup	On, Off	Off
VVI Backup Pacing Rate (ppm, min^{-1})	30, 35, . . ., 120	60
VVI Backup Amplitude (V)[d]	0.5, 1, . . ., 4, 5, 6	4[b]
VVI Backup Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . .,1.6	0.5[b]

Table B-7 System test and EP study parameters (continued)

Parameter	Selectable values	Default
PES Induction Parameters		
Chamber	Ventricle, Atrium	Ventricle
#S1	1, 2, . . ., 15	8
S1S1 (ms)	100, 110, . . ., 2000	600
S1S2 (ms)	Off, 100, 110, . . ., 600	400
S2S3 (ms)	Off, 100, 110, . . ., 600	Off
S3S4 (ms)	Off, 100, 110, . . ., 600	Off
Pulse Amplitude (V)[d]	0.5, 1, . . ., 4, 5, 6, 8	4
Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . ., 1.6	0.5
Resume at Deliver	Enabled, Disabled	Enabled
VVI Backup	On, Off	Off
VVI Backup Pacing Rate (ppm, min^{-1})	30, 35, . . ., 120	60
VVI Backup Amplitude (V)[d]	0.5, 1, . . ., 4, 5, 6	4[b]
VVI Backup Pulse Width (ms)	0.03, 0.06, 0.1, 0.2, . . .,1.6	0.5[b]
Manual therapy parameters		
In general, each manual therapy provides the same parameter values as the automatic therapy. See Table B-3.		

[a] The selectable values for this parameter depend on the programmed pacing mode.

[b] The default value for this parameter is set according to the permanently programmed settings for bradycardia pacing if the device has been interrogated. Otherwise it defaults to the indicated nominal value.

[c] The maximum range value is dependant on the programmed pacing mode.

[d] Peak pacing amplitude. When tested per Cenelec standard 45502-2-1, the measured amplitude A depends upon the programmed amplitude A_p and programmed pulse width W_p: $A = A_p \times [0.9 - (W_p \times 0.145\ ms^{-1})]$.

[e] Delivered energy based on a biphasic pulse into a 75 ohm load. For energy less than 1 joule, tolerance is ± 0.25 J.

Fixed parameters

Table B-8 Fixed parameters

Parameter	Fixed value
Fixed blanking periods	
Atrial blanking after a sensed atrial event	100 ms
Atrial blanking after a paced ventricular event	30 ms
Atrial blanking after high voltage therapy	520 ms
Ventricular blanking after a sensed ventricular event	120 ms
Ventricular blanking after a paced atrial event	30 ms
Ventricular blanking on a high voltage pulse delivery	520 ms
Fixed bradycardia pacing parameters	
Ventricular Safety Pacing intervals	110 ms 70 ms[a]
PVC Response (PVARP extension)	Extended to 400 ms[b]
PMT Intervention (PVARP extension)	Extended to 400 ms[b]
Fixed high voltage therapy parameters	
Maximum charging period	30 seconds
Waveform	Biphasic
Tilt	50%
Refractory period after V-sense during cardioversion synchronization	200 ms
Refractory period after charge end	100 ms
Refractory period after paced event during charging or synchronization[c]	400 ms
Refractory period after charge begins[c]	400 ms
Atrial Vulnerable Period	250 ms
Escape interval after high voltage therapy	1200 ms
Suspension of VT detection after defibrillation therapy	17 V. events

Table B-8 Fixed parameters (continued)

Parameter	Fixed value
Fixed EP Study parameters	
T-Shock pacing amplitude[d]	8 V
T-Shock pacing pulse width	1.6 ms
50 Hz burst pacing interval	20 ms
Hardware parameters	
Atrial rate limit (protective feature)	171 ppm (min^{-1})[e]
Ventricular rate limit (protective feature)	171 ppm (min^{-1})[e]
Input impedance	100 kΩ minimum

[a] The shorter VSP interval takes effect when the pacing rate exceeds the results of the following formula: 60,000 / 2 x (Ventricular Pace Blanking + 110) per minute.

[b] PVARP is only extended to 400 ms if the current PVARP (either the programmed PVARP value or the current Sensor-Varied PVARP value) is less than 400 ms.

[c] Does not affect event classification during charging.

[d] Peak pacing amplitude. When tested per Cenelec standard 45502-2-1, the measured amplitude A depends upon the programmed amplitude A_p and programmed pulse width W_p: $A = A_p \times [0.9 - (W_p \times 0.145\ ms^{-1})]$.

[e] Does not apply during therapies, programmed high rates, or ventricular safety pacing.

Patient information parameters

Table B-9 Patent information parameters

Information field	Description and required action
Patient	Enter the patient name (up to 30 characters).
ID	Enter the patient ID (up to 15 characters).
Date of Birth	Select patient's date of birth.
ICD Number (Not selectable)	Displays serial number for implanted device after interrogation.
Lead 1 . . . Lead 2 . . . Lead 3 . . .	Enter detailed information for leads 1, 2, and 3: Model, Position: pick from list of positions, or enter position, Serial Number, Manufacturer, and Implant date.
Implant	Enter measured values from implant. Using the displayed submenu, enter new information including lead data from the Analyzer.
Notes	Enter notes about patient or other information.
History (2 fields)	Select medical history from list box. If necessary, you can indicate that more information is located in the Notes field.
EF, on	Select the ejection fraction from a table of values. Then enter the date in the following field.
Physician	Select or add the name of the physician. You can also enter the physician's phone number at the same time.
Phone	Enter the phone of the physician.
Hospital	Select or add the hospital information.
Last Update (Not selectable)	Displays the date of the last Patient Information update.

Programmer symbols

Table B-10 shows some symbols the programmer may display on the screen while you are programming the device and describes their meaning.

Table B-10 Programmer symbols

	Nominal – Indicates the Medtronic nominal value for a parameter.
	Programmed – Indicates the value currently programmed in the device for a parameter.
	Interlock – Appears when one selected value is incompatible with another value. You cannot program the device to this setting until you resolve the parameter interlock (see “Parameter interlocks” on page 386).
	Warning – Indicates a value has an associated warning. You can still program this value, but the programmer will display the warning.
	Informational – Indicates additional, possibly cautionary information associated with the selected values. You can program these values, but the programmer provides information for you to consider.

Parameter Interactions Window

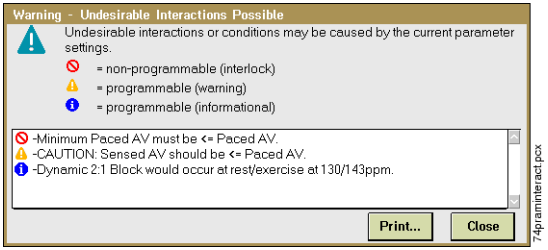
The Parameter Interactions window displays details that correspond to interlock, warning, and information symbols marking displayed parameters on the current screen.

Also, if the displayed screen contains either an interlock, warning, or information symbol, one of the following icon buttons appears next to [Program] at the bottom of the screen, for example:

Figure B-1. Parameter icon buttons

Select the icon button from the bottom of the screen to display the Parameter Interactions window.

Figure B-2. Parameter Interactions Screen


Warning - Undesirable Interactions Possible
Undesirable interactions or conditions may be caused by the current parameter settings.
= non-programmable (interlock)
= programmable (warning)
= programmable (informational)
-Minimum Paced AV must be <= Paced AV.
-CAUTION: Sensed AV should be <= Paced AV.
-Dynamic 2:1 Block would occur at rest/exercise at 130/143ppm.
Print...
Close
74pramInteract.pcx

Parameter interlocks

The programmer software restricts specific programming situations to ensure that tachyarrhythmia detection is safe and effective and that bradycardia features operate properly. These software restrictions are referred to as interlocks. If a restricted programing situation is attempted, an interlock message appears on the programmer screen stating the reason for the restriction.

Interlocks can be summarized by the following categories:

- General Safety

  These interlocks adhere to normal programming conventions. For example, the programmer does not allow programming of the FDI greater than the TDI.

- Maintain a ventricular sensing window

  These interlocks limit parameter values in order to maintain 50% of the VP - VP interval as a ventricular sensing window. This helps to ensure detection of a ventricular arrhythmia during ventricular pacing. For example, Ventricular Pace Blanking must be programmed to a value less than or equal to ½ the lower rate interval.

- No pacing in the detection zone

  These interlocks prevent programming of pacing intervals in the detection zone. For example, they prevent an atrial pace during the VTDI (or VFDI), since cross chamber sensing could cause an inappropriate detection of a ventricular tachycardia. These interlocks also prevent under-detection due to cross-chamber blanking.

- No bradycardia pacing in or near the VT detection zone

  These interlocks limit parameter values in order to maintain a 30 ms period between the atrial pacing interval and tachyarrhythmia detection interval and avoid intrinsic conduction in the VT detection zone.

- General bradycardia

  These interlocks ensure that the Brady features operate properly. For example, Single Chamber Hysteresis cannot be be turned on at the same time as Ventricular Rate Stabilization because these two features have opposing actions.

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